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Bulletin 845

GUIDEBOOK
OF THE
WESTERN UNITED STATES

PART F. THE SOUTHERN PACIFIC LINES
NEW ORLEANS TO LOS ANGELES

BY

N. H. DARTON

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Principal divisions of geologic time [a]

Era	Period	Epoch	Characteristic life	Duration,[b] millions of years
Cenozoic (recent life).	Quaternary.	Recent. Pleistocene (great ice age).	"Age of man." Animals and plants of modern types.	60
	Tertiary.	Pliocene. Miocene. Oligocene. Eocene.	"Age of mammals." Possible first appearance of man. Rise and development of highest orders of plants.	
Mesozoic (intermediate life).	Cretaceous.	([c])	"Age of reptiles." Rise and culmination of huge land reptiles (dinosaurs), of shellfish with complexly partitioned coiled shells (ammonites), and of great flying reptiles. First appearance of birds and mammals (in Jurassic); of cycads, an order of palmlike plants (in Triassic); and of angiospermous plants, among which are palms and hardwood trees (in Cretaceous).	120
	Jurassic.	([c])		
	Triassic.	([c])		
Paleozoic (old life).	Carboniferous.	Permian. Pennsylvanian. Mississippian.	"Age of amphibians." Dominance of club mosses (lycopods) and plants of horsetail and fern types. Primitive flowering plants and earliest cone-bearing trees. Beginnings of backboned land animals (land vertebrates). Insects. Animals with nautiluslike coiled shells (ammonites) and sharks abundant.	120
	Devonian.	([c])	"Age of fishes." Shellfish (mollusks) also abundant. Rise of amphibians and land plants.	90
	Silurian.	([c])	Shell-forming sea animals dominant, especially those related to the nautilus (cephalopods). Rise and culmination of the marine animals sometimes known as sea lilies (crinoids) and of giant scorpionlike crustaceans (eurypterids). Rise of fishes and of reef-building corals.	30
	Ordovician.	([c])	Shell-forming sea animals, especially cephalopods and mollusklike brachiopods, abundant. Culmination of the buglike marine crustaceans known as trilobites. First trace of insect life.	90
	Cambrian.	([c])	Trilobites and brachiopods most characteristic animals. Seaweeds (algae) abundant. No trace of land animals found.	60
Proterozoic (primordial life).	Algonkian.	([c])	First life that has left distinct record. Crustaceans, brachiopods, and seaweeds.	1,200±
	Archean.	Crystalline rocks.	No fossils found.	

[a] The geologic record consists mainly of sedimentary beds (beds deposited in water). Over large areas long periods of uplift and erosion intervened between periods of deposition. Every such interruption in deposition in any area produces there what geologists term an unconformity. Many of the time divisions shown above are separated by such unconformities; that is, the dividing lines in the table represent local or widespread uplifts or depressions of the earth's surface.

[b] Ages interpolated from Holmes, Age of the Earth, New York, Harper & Bros., 1927.

[c] Epoch names omitted; in less common use than those given.

NOTE.—Total estimated age of earth, 1,800± million years.

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GUIDEBOOK OF THE WESTERN UNITED STATES

PART F. SOUTHERN PACIFIC LINES, NEW ORLEANS TO LOS ANGELES

By N. H. DARTON

INTRODUCTION

The Southern Pacific Railroad from New Orleans to Los Angeles, a distance of about 2,000 miles, passes through a region exhibiting a great variety of geographic and industrial conditions. The climate, especially the amount of precipitation, is the most influential factor in causing this variety. (See pl. 1.)

The low Coastal Plain of southern Louisiana and eastern Texas, with ample rainfall and thick rich soils, is a province distinct in configuration, human occupations, and products. There are extensive swamps, prairies, and wooded areas, but a large part of the land is under cultivation, with sugarcane, cotton, and rice as the principal crops. The streams are wide and slow, the winter climate is mild, and the summer heat is tempered by breezes from the Gulf of Mexico. Flourishing towns occur at short intervals, and some of them are growing rapidly. The entire region is underlain by a great thickness of sand and clay of alluvial origin.

In central-eastern Texas the Coastal Plain is higher, the soil conditions are materially different, the streams run more swiftly, swamps become rare, and although much land is under cultivation, many areas are either in pasture or not cleared. The vegetation changes with change of soil and increase of altitude, and the crops are more diversified than in the lower parts of the Coastal Plain. The region is underlain by sandstone, shale, and other formations, which rise toward the west, cropping out in regular succession as they are crossed from east to west. Some of these formations are hard enough to make ridges and knobs, and there is general terracing at various levels. Parts of the highest lands are remnants of an old plain of former wide extent.

Beyond San Antonio the traveler observes several changes in the general aspect of the country, for although the Coastal Plain extends west to Del Rio, there is both a gradual increase in elevation to about 1,000 feet and a marked diminution of rainfall to the west, which greatly affect landscape and industries. Cacti become larger and more abundant, and many special trees and plants are prevalent, notably the mesquite; forests diminish in density, and far to the west trees occur only in the bottom lands. Agriculture here depends largely on irrigation, and the raising of cattle, sheep, and goats is the dominant industry. The principal underlying rocks are shale, soft sandstone, and chalk, which do not make strong relief but produce hills and ridges of moderate height separated by wide valleys, which along the larger streams are bordered by bottom lands. Northwest of San Antonio the Coastal Plain gives place rather abruptly to the Edwards Plateau, owing to the rapid rise of hard limestones; from San Antonio to Del Rio this feature lies north of the railroad but is visible at many places.

For many miles west from Del Rio the railroad is on the plateau, which is floored by hard limestone and deeply trenched by the drainageways, notably by the canyons of the Devils River, the Rio Grande, and the Pecos River. In this district, where semiarid conditions prevail, vegetation is sparse and trees are mostly confined to valley bottoms except where the limestone supports a growth of juniper or live oak. The soil is thin, but it sustains grass and shrubs which afford good pasturage for many goats, sheep, and cattle. Owing to the gradual general rise of the strata to the west the land increases in elevation, and much of the plateau in south-central Texas is 2,000 feet above sea level in its eastern part and 3,000 feet in its western part. Near Sanderson this rise develops into the great dome of the Marathon uplift. The central part of this uplift is truncated, revealing a large area of closely folded Paleozoic rocks, making sharp ridges of the Appalachian type. The Edwards Plateau ends on the east side of this uplift. To the west is the Davis Mountain region, a wide province of volcanic rocks, characterized by rugged peaks and irregularly disposed ridges in great variety, which rise to elevations considerably more than 6,000 feet.

The volcanic rocks continue far west of Marfa, but near that place begins the Basin and Range province, which extends thence across New Mexico, Arizona, and southern California. In this province there is a prevalence of long ridges separated by wide plains or bolsons floored by sand and gravel. They present a succession of strata or of volcanic flows, mostly tilted or flexed and faulted. Many of the great mountain faces stand along lines of uplift. At intervals there are large masses of intrusive rocks, which have been forced up in a molten condition and are now so hard that they are conspicuous topographic features.

The climate of this region is arid or semiarid. The Rio Grande flows between ridges in New Mexico, but at and below El Paso it either crosses the axes of the ridges in canyons or passes around their ends. The Gila and Colorado Rivers have similar relations in southwestern Arizona after leaving the canyons in which they cross the Arizona Plateau. The mountains of the Southwest are rocky and jagged, and the meager vegetation is so scattered that they appear to be bare. The broad desert plains of gravel and sand between the mountains likewise sustain only scant vegetation, for this is the most arid province in the United States. Parts of it, however, that have water for irrigation are highly productive.

The San Bernardino, San Jacinto, and associated mountain ranges in California form high barriers on the north and west sides of the Salton Basin which intercept the moist air currents from the Pacific and thus cause the aridity that prevails over a wide area to the east. These mountains are uplifted blocks, made up largely of granitic and metamorphic rocks.

In southern California lowlands extend from the mountain slopes east of Redlands to the Pacific Ocean, a distance of about 120 miles. The surface slopes mostly to the west and south and is diversified by scattered rocky ridges. The climate is mild, and although the precipitation is only moderate in amount, water is available for irrigation and wide areas are under cultivation for citrus fruits, grapes, nuts, and many other valuable crops.

In these days of wide culture it is hardly necessary to point out the practical utility of geologic knowledge and the relation that exists between geology and the occurrence of nearly all materials of economic value. Soils are derived by geologic processes from rocks of various formations. Ores, minerals, oil, coal, and water all have close relations to the structure and history of the geologic formations in which they occur. Some igneous rocks carry or have been the source of ores, and their history and relations have much to do with mining.

The order and general succession of the strata making up the rocky shell of the earth are shown in the table on page II. The oldest rocks now seen at the earth's surface include some granites and other crystalline rocks, partly of igneous origin and partly of other types that have become crystalline through the agency of heat and pressure within the earth and have later been exposed by erosion. These are overlain by a great succession of sedimentary strata (laid down by water), consisting of sandstone, limestone, and shale, which have a thickness of many thousand feet. Some of these later rocks have also been altered by heat and pressure into schist, marble, and quartzite. In many areas there are lavas, ash, and tuff extruded by volcanic action at various times, some of it recent. Seas, lakes, and rivers have been the principal agents in depositing sand, clay, and limy sediments, which have later become sandstone, shale, and limestone. In general, sands were deposited mainly on the shores and by streams, clays in quieter waters, and limestones in deeper waters, so that these various materials indicate the geologic conditions at the time of their deposition. The wind has also played some part in the accumulation of sand, and much detrital material has been moved by glaciers. The character of the rocks and the order of the sedimentary succession vary in different regions; thus a system may be fully represented in one district and be entirely or partly absent in another, owing to lack of deposition or to removal by erosion in an interval of uplift. In some places a portion of geologic time may be represented by limestone alone, while in others the same portion is represented by shale, sandstone, or volcanic rocks. Fossil shells, bones, and other parts of organisms throw light on the succession of sedimentary rocks, for they mark the progress of life development through geologic time; they are the key to geologic problems, such as the structure and order of formations, that in many places could not be solved without them.

The total thickness of the sedimentary formations is many thousand feet, and the time represented is hundreds of millions of years.

NOTE.—For the convenience of the traveler the sheets of the route map in this bulletin are so arranged that they can be unfolded one by one and kept in view while reading the related text. The contour lines, in brown, represent elevation above sea level. Each line indicates the path that would be taken by one who walked over the country by a course always at the same level, curving in and out with the irregularities of the land surface. The lines are drawn at the vertical distances apart ("contour interval") stated on each map; where these lines are close together they indicate a steep slope; where they are far apart, a gentle slope or plain. Most of the contour lines have been compiled from detailed topographic maps published by the United States Geological Survey, the names of which are given in the southwest corner of each. In some areas the contour lines are taken from surveys by the Engineer Corps, U. S. Army, and the Los Angeles Department of Water and Power, and from reconnaissance by the author. A reference to each map is made in the text at the place where it should be unfolded. The areas covered by these sheets are indicated on Plate 2, and a list of the sheets and the other illustrations is given on pages III–VII.

Figures given on mileposts in Louisiana indicate miles from Algiers, a Southern Pacific freight terminal on the south bank of the Mississippi River opposite New Orleans; they are about 1⅓ miles less than the distance from the Union Station, New Orleans. West of Houston the mileposts give distances from Harrisburg, an old terminal off the present main line about 3 miles south of Houston station. West of El Paso the mileposts give distances from San Francisco. As a rule the mileage given on the posts does not allow for differences due to subsequent shortening or lengthening of the line. Most of the elevations at stations given in this guidebook are those furnished by the railroad company, but others are derived from precise levels of the United States Coast and Geodetic Survey or the United States Geological Survey.

The statistics given in this guidebook are taken mainly from official Government sources, such as the United States Census and the United States Bureau of Mines. Some have been derived from local sources that are believed to be reliable, and these are credited to the respective authors. Statistics not otherwise credited are to be understood as obtained from official Government records, whether so stated or not. Authors' names cited in parentheses refer to the bibliography on pages 293–296.

ITINERARY

NEW ORLEANS, LA., TO LOBO, TEX.

New Orleans.
Elevation 6 feet.
Population 458,762.[1]

The journey westward over the Southern Pacific lines begins at New Orleans, one of the largest cities in the United States and one that is unique in character, history, environment, and economic relations. Founded in 1718 by Capt. Jean de Bienville, as a nucleus of a French settlement in America, it was named in honor of the Duke of Orleans, the regent of young Louis XV. It was colonized mostly by people from France, and a part of the population still follows the customs and traditions of their French ancestors. The city consists of two portions, presenting the strong contrast of the quaint old French with the new American.

The area of the original palisaded city is now known as the "Vieux Carré"; it centers about the old St. Louis Cathedral in the Place d'Armes, now Jackson Square, laid out in 1720 by Le Blond de la Tour, Bienville's engineer. A few French and a great many Spanish houses, built from 100 to 150 years ago, still remain; once the homes of aristocratic and distinguished people, they are now mostly converted into trading establishments and rooming houses. The Place d'Armes has been the scene of many historic events, notably the gathering of troops to repel the expected attack of the Natchez Indians in 1728, the reception of the Acadians driven from Nova Scotia by the British in 1755, the arrival of Gen. Alejandro O'Reilly in 1769 to take possession after the transfer of the colony from France to Spain, and the triumphant return of Gen. Andrew Jackson from the Battle of New Orleans January 8, 1815. Here also were made the three great transfers of Louisiana Territory subsequent to the treaties of cession—first from France to Spain in 1764, then from Spain to France in 1803, and finally, in 1803, from France to the United States, a transaction very distressing to many of its Creole inhabitants but resulting quickly in marked increases in property values and population.

The cathedral, erected in 1795 by Don Almonaster y Roxas, who is buried under the altar, replaced a small church built in 1718 and destroyed by fire in 1788. Next door is the Cabildo, built in 1795 for the Spanish Legislature and for nearly a century the seat of government. Adjoining the cathedral is the Presbytère, formerly the house of the Capuchin priests, used later for the civil courts of the city.

[1] The figures given in this book for population of incorporated places are those of the United States Census for 1930. For some of the small places the population has been estimated, and such figures are marked with an asterisk (*).

This and the Cabildo are now part of a free museum and the home of the Louisiana Historical Society. Not far distant is the house built for Napoleon, who was to have been rescued from St. Helena by one of Lafitte's pirate crew had he not died before the expedition could start. Many other buildings near by have great historic interest and also present peculiarities of construction not seen elsewhere. The city was largely destroyed by fires in 1788 and 1794; in its rebuilding the Spanish influence has affected the architecture. The French market (shown in part in pl. 3, *A*), on the site of the market built by the Spaniards in 1791, attracts many tourists. Not far away (1727 Chartres Street) is the Archbishopric, erected in 1734 for an Ursuline convent, said to be the oldest building now standing in the Mississippi Valley. Rampart Street is on the outer line of the city defenses, built in 1793 by Baron de Carondelet, then Spanish governor, and the Terminal Station is on the site of Fort Burgundy. The old cemeteries are filled with vaults, many with three tiers of niches for caskets, for originally the water level was so near the surface that burial in the ground was impracticable. (See pl. 3, *B*.) The Spanish fort where Bayou St. John joins Lake Pontchartrain marks the place where the first colony landed. The Chalmette Monument, in the lower end of the city, commemorates the battle in which Gen. Andrew Jackson and his 5,000 backwoods militia routed a good-sized British army under Sir Edward Pakenham in 1815. The mint, erected in 1821, the oldest one in the country, was built on ramparts of General Jackson's old fort. The Pontalba buildings, still in use, were erected in 1849 and were long used as high-class apartment houses. In 1862 New Orleans was captured by Gen. Benjamin Butler and held by the Union forces until the end of the Civil War.

New Orleans is built on the "Isle d'Orléans" (no longer an island) in a great crescent-shaped bend of the Mississippi 107 miles above its mouth (South Pass). It lies on the slope of a natural levee, or low ridge built up by the river, and comprises an area of 44 square miles. Most of the city is below the high-water level of the river, and parts of it are below the level of the Gulf of Mexico.[3] The first levee, built

[3] The land slopes down from the river bank into two basins 1 foot or more below sea level—one north of Claiborne Avenue and another in the neighborhood of Earigny and Elysian Field Avenues. North of these basins there is a ridge with crest 3 to 5 feet above sea level that was probably built by Bayou Sauvage and later cut through by Bayou St. John. North of this ridge the land is less than 1 foot above sea level and slopes gently to Lake Pontchartrain. The sediments under New Orleans are sand, silt, and clay, probably of the overflow or levee deposits, though they may have been deposited in the Gulf in front of an offshore bar. In the sediments are undecayed cypress stumps, some as deep as 12 feet below sea level. At depths of more than 43 feet below sea level recent marine shells are found (Trowbridge). It has not been definitely determined how much true delta material underlies New Orleans.

in 1727, was 900 feet long; eventually, as levees were extended, the city developed in a wide, deep saucer, out of which no drainage could flow. Throughout its history, therefore, it has had to contend with flood overflows, rain water, seepage, and sewage removal. Now, however, pumps with a capacity of 7,000,000,000 gallons a day lift surplus water into Bayou Bienvenue and Lake Pontchartrain. At times of heavy downpours the volume of water to be handled is very great,[4] but it is claimed that the present pumping system can dispose of a rainfall of 14 inches in 24 hours. The annual precipitation is 57 inches. The sewage is pumped to an outlet down the river, 20 feet below mean water level. Surface water and seepage are collected in large canals, and by this means the general ground-water level has been so greatly lowered that cellars are practicable and graves can be dug where formerly all interments were made in tombs.

In these days of large buildings it has been difficult to obtain stable foundations, but by the use of many wooden piles, in some places 80 feet long, office buildings and hotels of considerable height have been erected.[5] One notable structure is the auditorium, which has a seating capacity of 12,000 and is used for the great balls of the Mardi Gras festival.

There are four great institutions of learning in New Orleans: Tulane University (formerly the University of Louisiana), the H. Sophie Newcomb Memorial College (the women's department of Tulane University), Loyola University, and the Isaac Delgado Central Trades School. There are many parks, libraries, churches, and clubs. About two-thirds of the population are native whites. The city water supply, of about 50,000,000 gallons a day, is pumped from the river, and plans have been developed to double this amount; the water is purified by treatment, so that its quality is satisfactory. New Orleans once had a high death rate, but this has been reduced by sanitary measures to 12½ per 1,000 for the resident population, according to local records. The dreaded scourges of yellow fever and bubonic plague have been eliminated, and malaria has been made

[4] One night in April, 1927, a fall of 13 inches of rain caused such an inundation that the levees had to be opened at Poydras, 15 miles below the city, to let out the flood waters, an expedient that cost the city $5,000,000 for damages. Now a spillway 35 miles above the city serves to divert water into Lake Pontchartrain in times of river flood.

[5] In building most of the railroad embankments a great canal was first excavated to remove mud and then filled with sand. For foundations in the lower part of the city 30 feet or more of silt is removed to a layer of long-buried cypress stumps, through which closely spaced piling is driven to form a mesh which by friction will sustain heavy buildings. One high building with a foundation of this character has settled a few inches, but the subsidence has been so uniform that there is no rupturing. In some places even the lowering of water level by drainage has resulted in the decay of wooden substructures with consequent settling of buildings.

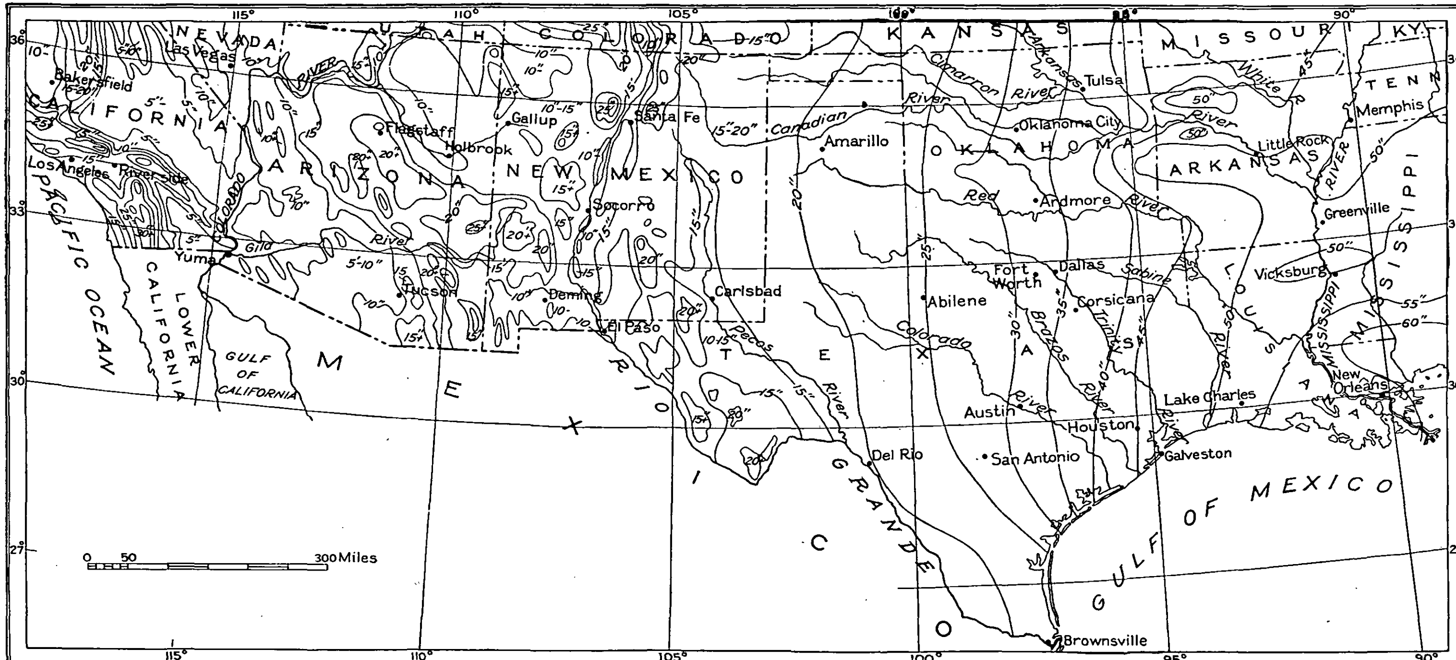
rare.[6] Although in latitude 30°, and with a warm climate for much of the year, the mean annual temperature is only 69.3°, with rather small seasonal range from 54° in January to 82.4° in July.

New Orleans has become a great commercial center, as much of the vast foreign commerce of the Mississippi Valley and central United States passes through its portals. It is reached annually by about 1,000 vessels whose capacity in 1928 amounted to 11,204,573 tons, according to the New Orleans Association of Commerce. It is a port of entry for a large part of our business with Latin-American ports. It claims to be the largest market in the United States for cotton, bananas, rice, and burlap and one of the largest for sugar, mahogany, coffee, furs, hides, and naval stores. According to statements furnished by the New Orleans Association of Commerce, from 350,000,000 to 450,000,000 pounds of coffee, 500,000 bales of cotton, and 23,000,000 bunches of bananas are handled every year. The grain elevators have a capacity of 2,622,000 bushels. The imports in 1928 amounted to $208,430,587 and the exports to $384,597,092, all transported on the Mississippi River through the great passes at its mouth. This river at New Orleans is 2,000 feet wide and in places 200 feet deep. Although there is provision for many vessels on the city's long water front, additional space to accommodate the heavy traffic has been obtained by the construction of a canal 30 feet deep and 5 miles long, connecting the river with Lake Pontchartrain. This canal has a huge lock to provide for the drop from river to Gulf level and cost $21,000,000.

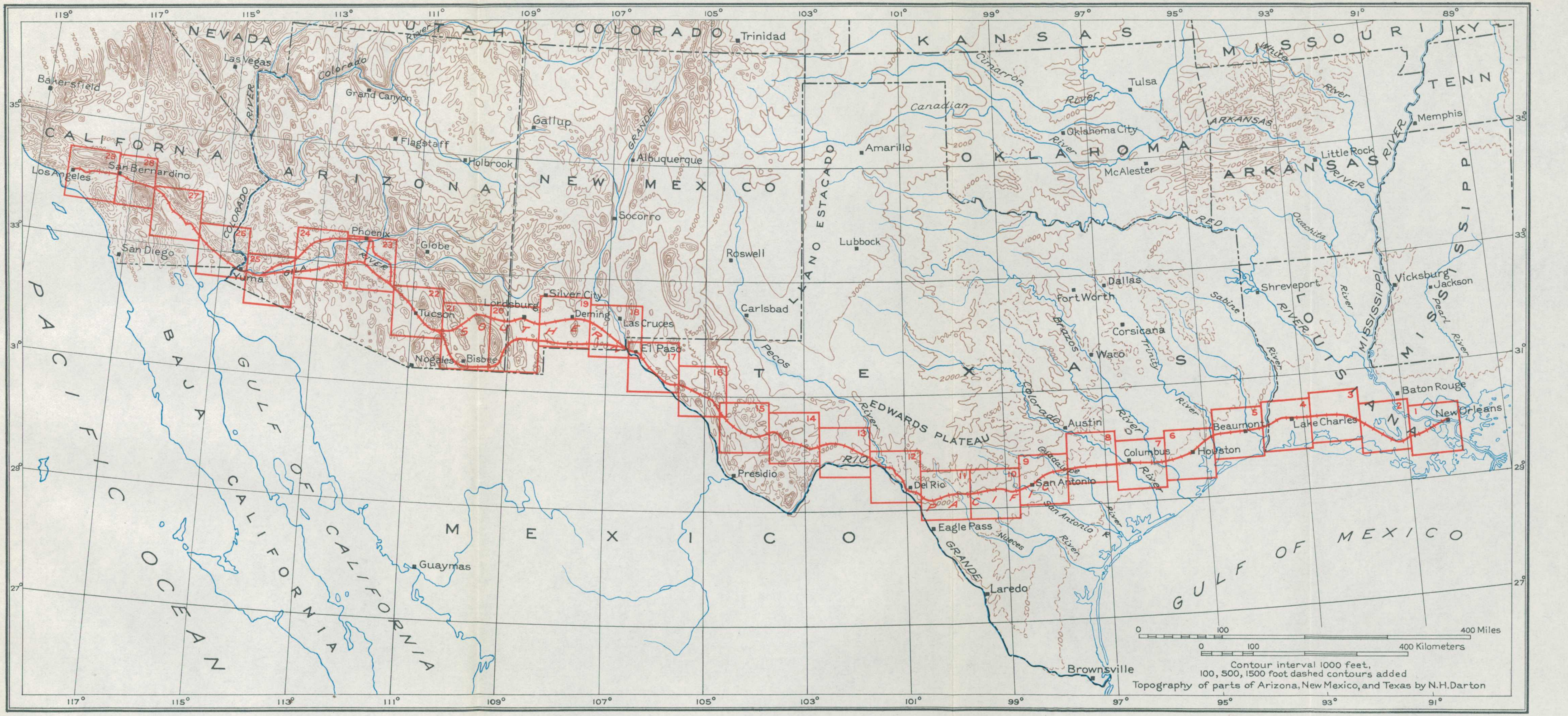
In order to permit the access of large ocean-going vessels to New Orleans, two of the outlet channels, South Pass and Southwest Pass, at the mouth of the Mississippi River, originally having only 10 or 12 feet of water, have been dredged to depths of 30 to 35 feet, with widths of 750 to 1,000 feet. The filling of these channels by the great volume of silt carried by the river is prevented by a current of sea water which passes under the fresh-water outflow, forming a deep-seated eddy which keeps the sediment in suspension and carries it off. Great care, however, has to be taken to prevent the river from creating new passes, which would decrease the strength of the current in the main channel and diminish its effectiveness in transporting sediment.

New Orleans is also a great manufacturing center, the 1929 output of its 786 factories being valued at $148,388,315, according to the United States Census. Its manufacturing industries have the great advantage of natural gas from the Monroe field, in Louisiana, cheap

[6] In the summers of 1853 to 1855 there were 37,000 deaths from yellow fever, at times at the rate of 300 a day. In 1889 the death rate from malaria was 156 per 100,000; now it is 1. Since the present water supply has been established the death rate from typhoid fever is only 2 per 100,000. (Data from New Orleans Association of Commerce.)



MAP SHOWING PRECIPITATION IN THE SOUTHWEST



WILLIAMS & HEINTZ CO., WASH., D. C.

CONTOUR MAP OF THE SOUTHWESTERN UNITED STATES

Areas shown on the route maps are outlined in red

A. OLD FRENCH MARKET IN VIEUX CARRÉ, NEW ORLEANS

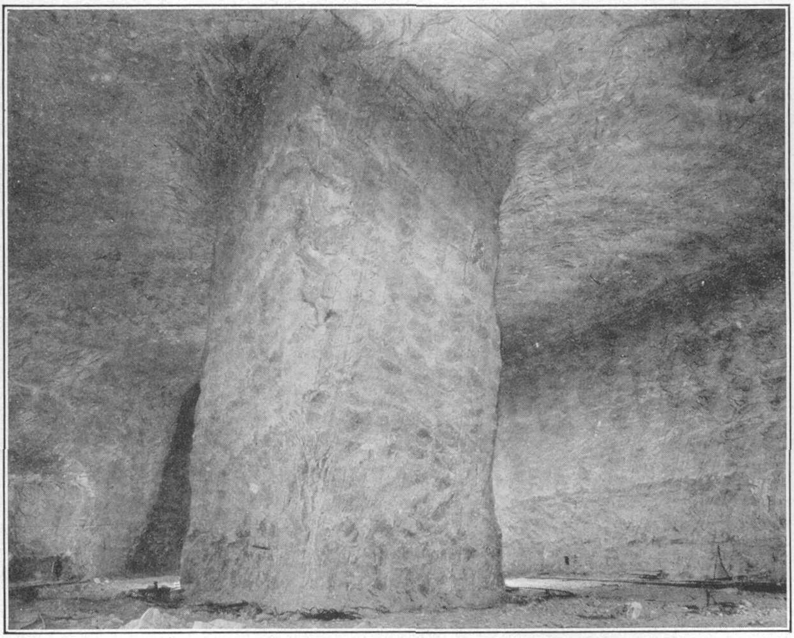
Looking out a typical street in center.

B. TYPICAL GRAVEYARD IN NEW ORLEANS

In the early days the water plane was so near the surface that interment was undesirable.

A. WOODLAND SCENE, SOUTH-CENTRAL LOUISIANA

Showing the parasitic Spanish moss.



B. GALLERIES IN THE SALT MINE, AVERY ISLAND, LA.

oil, and water transportation. Sugar, cane sirup, cotton goods, and celotex (board made from bagasse, or sugarcane refuse) are important local products.

Louisiana.

Louisiana, with an area of 48,506 square miles, had in 1930 a population of 2,101,593, an increase of nearly 17 per cent since 1920, placing it twenty-second in rank in the United States. Owing to large areas of thinly populated swamp lands, however, the average density of population is only 43 to the square mile. New Orleans is by far the largest city. Shreveport, which is growing rapidly, is next in size; Baton Rouge (the capital), Monroe, Alexandria, Lake Charles, and Lafayette are considerably smaller.

The greater part of Louisiana consists of lands less than 100 feet above sea level, and a large area along the Mississippi River and the Gulf coast stands at less than 50 feet. The alluvial valley of the Mississippi occupies all of the eastern half of the State. There are more than 4,700 miles of waterways, but some of them are small. A great intracoastal canal utilizing many of these natural waters is in course of construction. (See p. 17.)

The principal products of Louisiana are agricultural, with crop values of $161,078,688 in 1929,[7] but only about one-fifth of the area is under cultivation. Furs, lumber, petroleum, natural gas, and miscellaneous manufactures, especially sugar refining, are sources of large income. In 1929, 402,422 acres of rice yielded 16,317,463 bushels, 1,945,354 acres of cotton yielded 798,828 bales, and 205,394 acres of cane yielded 208,000 short tons of sugar.[8] Corn production was about 20,000,000 bushels. According to data from the New Orleans Association of Commerce, the lumber cut in 1928 was 2,278,442,000 board feet, the State ranking second in the production of pine lumber, and its value, together with turpentine, rosin, tar, and other naval

[7] Statistics are taken from United States Census reports except as otherwise stated.

[8] Sugarcane was introduced from Santo Domingo by Jesuits in 1751, but not until 1780, when slave labor was utilized, did its cultivation become profitable. Louisiana grows about 95 per cent of the sugarcane raised in the United States and also imports considerable raw sugar for its refineries. For a while the extinction of the sugar industry was threatened by a blight called the mosaic disease, but it was saved by the substitution of cane imported from Java, which not only resists the disease but is more hardy in general, has a higher sugar content and tougher fiber, and requires replanting only every second or third year, instead of annually. According to data furnished by the New Orleans Association of Commerce, 200,000 acres of this cane was growing in 1929, with a yield of over 18 tons of cane to the acre, or more than double that of the earlier cane, and yielding 160 pounds of sugar to the ton, instead of 138 pounds. The 1929 sugar crop ranked next to cotton and rice in value. Sugarcane makes a heavy draft on the soil, but many fields have been producing it for 100 years or more.

152109°—33——2

stores and wood pulp, was $154,766,819. The petroleum production in 1931 was 21,804,000 barrels, according to the United States Bureau of Mines. Refining of petroleum is one of the principal industries, with an output in 1929 valued at $151,966,142, or more than one-fifth of the total value of the manufactures of the State. The sugar refineries in 1929 had a production valued at $74,706,373. Natural gas is obtained in several fields. The Monroe field gave 103,000,000,000 cubic feet in 1931, much of which was piped to many cities, although some was used at the source for the production of carbon black, of which Louisiana produced 28,740 tons in 1931. (U. S. Bureau of Mines.)

There is a large yield of fruits and early vegetables in Louisiana, and pecan nuts are an important product. The annual output of oranges, both Louisiana Sweets and Satsumas, is about 82,500 boxes. On account of the mild climate there is a long growing season, and in places three successive field crops can be raised in a year. Pastures are perpetual. Corn, which is increasing in popularity, yields 30 to 75 bushels to the acre. Rice, one of the principal crops, occupies a wide area in the southwestern part of the State, Louisiana ranking first in the United States in rice production. Hay is raised in large amounts, also lespedeza, or Japanese clover, which grows 12 to 15 inches high. Although many forest areas have been cut off, reforestation is in progress, and 500,000 acres has been planted in pines, to be sold years hence for lumber and pulp or to furnish turpentine. These plantings are mostly in areas not favorable to agriculture. Meanwhile, in order to conserve trees now developing, logs are imported to help supply the great sawmills at Bogalusa.

There are three game preserves in Louisiana, created to give sanctuary to the wild birds that live in or visit the State in vast numbers. These preserves are Avery Island, 34,000 acres; Rockefeller Preserve, 104,000 acres; and Russell Sage Preserve, 94,000 acres.

Louisiana is the largest producer of furs in the United States, for its great marsh areas sustain a vast number of fur-bearing animals. The muskrat is the one principally sought, and during the open season of 1928–29 about 5,000,000 pelts of this animal were obtained, at a value of about $1 each. These, with opossums, raccoons, minks, skunks, otters, wildcats, and foxes, yielded 6,000,000 pelts (equal to the Canadian production), valued at $8,500,000, according to data furnished by the New Orleans Association of Commerce. The pelts are all obtained by resident trappers, who in most places pay a rental for the land on which the trapping is done.

Louisiana produces many terrapin and shrimp, and according to local reports it ships 6,000,000 pairs of frogs' legs a year. Oysters are marketed in large numbers, and there is a vast area available for their culture, with the advantage that the oysters mature here in two years.

The great shell reefs on the Gulf shore are valuable for lime, road metal, chicken feed, etc.

Salt is one of the great resources of the State, with a production of 529,280 tons in 1931, valued at $1,962,690, according to the United States Bureau of Mines. A part of the salt is used for the manufacture of sodium carbonate, soda ash, caustic soda, and sodium sulphite, used for glass, in paper making, and in dyeing. Large factories in New Orleans produce these and other chemicals.

The Gulf region has an annual rainfall averaging about 62.5 inches, and although high temperatures occur during the summer, the heat is tempered by nearly constant breezes from the Gulf; these breezes also diminish the chill of the winter.

The history of Louisiana is full of interesting events, of which the first was the discovery of the mouth of the Mississippi River by the Spanish explorer, Pánfilo de Narváez in 1528. In 1542 Luis de Moscoso, who had accompanied Hernando de Soto to the mouth of the Red River, descended to the mouth of the Mississippi and sailed down the Gulf coast to Mexico. In 1673 Jacques Marquette and Louis Joliet, sent by the Canadian colonial government to find an outlet to the West, descended the great river to its junction with the Arkansas River, and in 1682 René Robert de La Salle sailed to its mouth, taking possession of the region under the name of Louisiana, in honor of his patron Louis XIV. The region claimed by La Salle included the entire drainage basin of the Mississippi River and much of the Gulf coast. Three years later he returned with a colony which he expected to locate near the mouth of the river, but he missed the Mississippi and landed instead at Matagorda Bay, in Texas, near which he was murdered in 1687. In 1699 Pierre d'Iberville, a French naval officer, landed at New Orleans with a colony, the first permanent settlement of the region, but he established it in Spanish territory (near Biloxi, Miss.). In 1712 Antoine de Crozat, a French merchant, obtained the exclusive right to trade in "Louisiana," but he surrendered this grant in 1717 to the Company of the West, which began sending out colonists. In the following year Capt. Jean de Bienville, a brother of Iberville, landed a colony of 68 persons at the site of New Orleans. In 1719 the first cargo of slaves arrived from Africa, valued at $150 each. This was just a century after the first slave cargo landed at Jamestown, Va. The seat of government was established in 1722 at New Orleans, and in 1726 the settlement had a population of 800. Life was made difficult by floods, Indians, diseases, and hurricanes. November 3, 1762, France, finding the territory a burden, ceded the portion west of the Mississippi, together with the city and island of New Orleans, to Spain in the secret treaty of Fontainebleau; the next year the remainder of Louisiana, east of the Mississippi, was ceded to England. The boundary between Spanish and British possessions, exclusive of the Isle of Orleans, was defined as the center of the Mississippi River. Spain, fearing that the settlements to the north would interfere with the interests of her possessions to the east, endeavored to defeat progress by prohibiting access to the mouth of the river. In 1800, in the secret treaty of San Ildefonso, Spain returned to France the area west of the Mississippi which she had acquired in 1762, but the actual transfer of authority was postponed for three years. On April 30, 1803, Napoleon ceded this territory to the United States for the sum of 60,000,000 francs and the assumption of certain claims against France. The part of Louisiana east of the river which was known as West Florida was ceded in part to Spain and in part to the United States by Great Britain in 1783. The Florida Purchase, effected by the United States in 1819, completed the transfer of Louisiana Territory.

The part of the State lying west of the Mississippi River was organized in 1804 as the Territory of Orleans, and in April, 1812 (the year the first steamboat made the trip from Pittsburgh to New Orleans), it was admitted to the Union under the name Louisiana. The area lying east of the river, although its ownership was disputed until 1819, was added to the State a short time later.

The present State of Louisiana is about one-twentieth of the area of the Louisiana Purchase, which was divided into 15 States. New Orleans was the capital until 1829 and again from 1831 to 1846.

Leaving the Union Station, New Orleans, the Southern Pacific train uses the tracks of the Illinois Central Railroad as far as Harahan Junction, a switch station on the north side of the Mississippi River. (Turn to sheet 1.) Thence the line crosses the river flat in a southerly direction and in 2 miles reaches the levee, over which it passes on an incline. Here on the bank of the Mississippi the entire train, divided in sections, is placed on a huge steel barge (*The Mastodon*) to be ferried [9] across the swift current to Avondale, on the southwest bank, a distance of nearly a mile. The floats are adjustable for different stages of the river, for there is considerable variation in the water level consequent on floods and droughts.

The Mississippi River, flowing past New Orleans to its great delta in the Gulf of Mexico, is the largest river in North America.[10] It has a drainage area of 1,231,492 square miles, and it flows across nearly the entire width of the United States.

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[9] This ferry is regarded as a temporary expedient, as a $20,000,000 bridge is projected.

[10] It is estimated by the Mississippi River Commission that the Mississippi River carries annually 500,000,000 tons of sediment. The average flow at New Orleans is from 135,000 to 1,360,000 cubic feet a second. There is a mean flow of 800,000 cubic feet a second at Old River, 130 miles above New Orleans, equivalent to a total annual discharge of 25,228,800,000,000 cubic feet.

At Avondale, not far south of the ferry, the train reaches the Southern Pacific tracks coming from Algiers, the terminal on the south side of the river opposite New Orleans, used only for freight. The land is low behind the levee, and most of it is too swampy for economical cultivation. In this area will be noted many cypress trees, water hyacinths, and other plants typical of the swamps and lowlands of the South. In wet places there are scattered palmettoes with their clusters of fan-shaped leaves. Most of the larger trees are festooned with the parasitic Spanish moss. A typical view in this region is given in Plate 4, *A*.

Avondale.
Elevation 8 feet.
New Orleans 13 miles.

To the small local settlement at Boutte the railroad proceeds along the natural embankment of the river and then follows a low ridge through the woodlands to Des Allemands, where Bayou des Allemands is crossed. This name is derived from a small settlement of Germans founded in colonial days, but the population now consists mostly of people of French origin living in primitive dwellings along the water's edge. For many years there was a sawmill here which cut cypress lumber from the adjoining swamp lands; now the supply of this material is practically exhausted, and the main resources are fishing, crabbing, and the trapping of muskrat and other fur-bearing animals.

Des Allemands.
Elevation 9 feet.
Population 400.*
New Orleans 33 miles.

In midsummer the water bodies in this region are spangled with a beautiful growth of the purple flowers of the water hyacinth. Bayou des Allemands empties into Barataria Bay, an inlet of the Gulf of Mexico, which was at one time the headquarters of the pirate Jean Lafitte.[11] Formerly some of the district about Des Allemands was reclaimed for agriculture by ditching and pumping. Now the first signs of extensive cultivation begin near Raceland Junction, where there are fields of cane supplying the large sugar refinery at Raceland, a short distance south. This refinery, which presses about 150,000

[11] This notorious person, about whom center hundreds of colorful legends of this region, ran a blacksmith shop in New Orleans in the early days of the nineteenth century (at 810 Chartres Street, just off Canal Street). At this time privateersmen in the Caribbean Sea were preying upon the vessels of countries that were hostile to the countries that hired them, and Lafitte became the agent through whom they disposed of the captured cargoes. In time he became the leader of a fleet of licensed privateersmen and established a fortified post on Barataria Bay. He trafficked extensively in slaves, at one time selling 450 negroes at public auction. The proceeds of these sales and his piratical booty buried for safe-keeping are still the object of treasure hunts in the bayou country. For his loyalty to the American forces in the War of 1812, his earlier outlawry was overlooked. He resumed his piracy in 1817 and moved his headquarters from Barataria Bay to Galveston Bay, where his fortifications continued until he was driven out in 1821. Apparently he was finally lost at sea.

tons of cane a season, draws part of its supply from more distant sources, some of it brought down the near-by Bayou Lafourche in barges. An interesting industrial development in the sugar industry in Louisiana is the utilization of the cane residue (bagasse) after the sugar-bearing juice has been pressed out. This material compressed into bales is shipped from many refineries to a large factory at Gretna, across the river from New Orleans, where it is pressed into sheets of building board known as celotex. In some of the cane fields at Raceland experiments are in progress to ascertain the results of using Chilean nitrates as fertilizer. Bowie siding is in the midst of cane fields, and there is a sugar refinery not far south of it.

The abrupt change in agricultural conditions at Raceland is due to the presence of a ridge of alluvium built up by sediments spread by the overflow of Bayou Lafourche. Alluvial uplands of this character are of great economic importance in many parts of the great valley of the Mississippi, for although not wide they have rich soils and are sufficiently high to afford good drainage, roadways, and places for settlement. On them are the principal farm lands in this part of Louisiana. The mound of Bayou Lafourche extends from the Mississippi River at Donaldsonville nearly to the Gulf of Mexico, a length of more than 100 miles. Its height for most of the distance is only about 15 feet, and its width is from 3 to 4 miles.

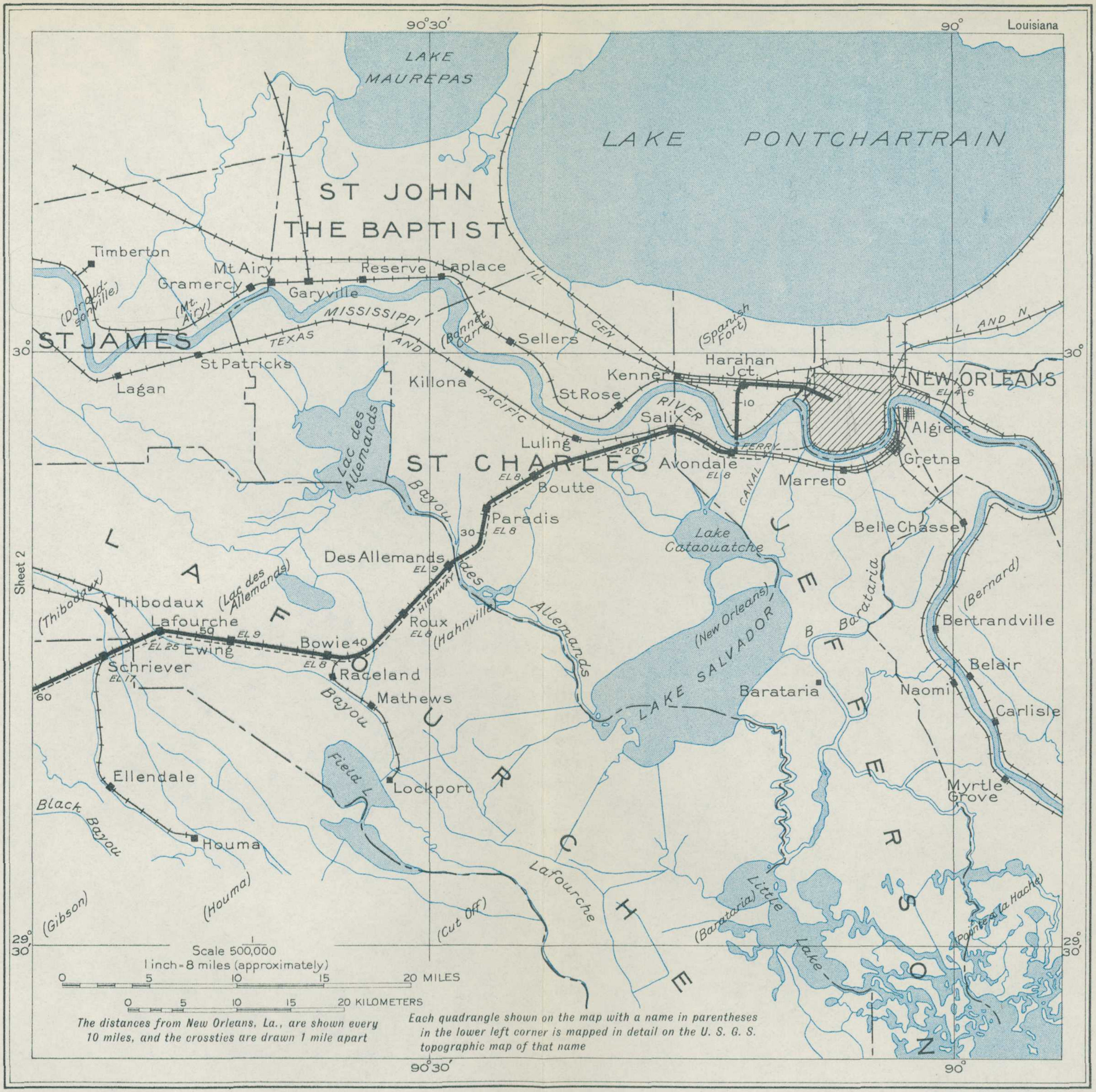
Lafourche.
Elevation 25 feet.
Population 60.*
New Orleans 53 miles.

Bayou Lafourche is the narrow stream crossed by the railroad just beyond Lafourche station. Originally this bayou was an outlet for part of the flow of the Mississippi River and was extensively utilized by freight boats, but to avoid the floods that occasionally came down the bayou, the connection at Donaldsonville was dammed off in 1903, and the navigability of Bayou Lafourche was greatly reduced. However, it is still used for traffic into the Mississippi River, with which it is connected by locks, and part of its lower course will be followed by the Intracoastal Waterway now projected across the lowlands, some distance south of the Southern Pacific lines.

Three miles northwest of Lafourche Crossing, but not visible from the railroad, is the town of Thibodaux (population 4,400), an old village of French origin, with important agricultural and commercial interests.

Schriever.
Elevation 17 feet.
Population 50.*
New Orleans 56 miles.

An alluvial ridge extends southward along Bayou Terrebonne through Schriever, and another, extending along Black Bayou, is followed by a branch railroad to Houma. At this old town there is a large sugar refinery and an extensive business in oysters and other gulf products. Much sugarcane is raised in this part of Louisiana, and formerly there were many small sugar refineries, some of which are still visible. Potatoes have lately become an impor-



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tant product, and considerable corn is raised. Between the alluvial ridges the land is low and swampy, but in places it can be drained by pumping; one notable reclaimed area of this kind southwest of Raceland is yielding large crops of corn. In the swamps cypress, tupelo gum, and other trees flourish. Lumbering has long been an active industry, but many years of vigorous lumbering has greatly reduced the amount of timber available. There was formerly a sawmill at Chacahoula, and at Donner a large mill is in operation on logs brought by rail and in "booms" rafted through the great system of waterways traversing the lowlands to the north. (Turn to sheet 2.)

Donner.
Elevation 11 feet.
Population 900.*
New Orleans 65 miles.

Donner is in the large lowland area that was covered by the great flood of the Mississippi River in 1927, when in the lower places the water was from 6 to 10 feet deep for several months. The flooded district extended far to the north and northwest over the lake region and the country traversed by the Grand and Atchafalaya Rivers. The bayou ridges described above (p. 14) were not covered, but the water extended far up their slopes. During the flood thousands of residents on the lower lands were driven out by the water, and there was considerable loss of crops and effects. The railroad embankment near Donner was slightly submerged, and parts of it had to be protected from the flood waters. In this region the roads are surfaced with oyster shells, which make an admirable road metal for light traffic. Shells are also burned as a source of lime.

Gibson.
Elevation 11 feet.
Population 60.*
New Orleans 67 miles.

Gibson is a small village on Black Bayou, a waterway of some importance. A quaint old church is about the only feature of special interest. Gibson was formerly an extensive lumber-milling community, drawing on the rich supplies, now mostly depleted, of cypress and other trees in the great swamp country to the north. This swamp vegetation is still a picturesque feature along the railroad in places, especially the drapery of Spanish moss on many of the trees.[12]

Boeuf.
Elevation 13 feet.
Population 300.*
New Orleans 74 miles.

The small old settlement of Boeuf is on the bank of an outlet of Lake Palourde, one of the water bodies of the widespread swamp region to the north. From Boeuf to Morgan City the railroad follows the north bank of Bayou Boeuf on a ridge of alluvium built up by overflows. In this general region the deposition of this material has also developed a series of islands of sufficient elevation for farming. They are not high, and in places the fields have to be protected from

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[12] Spanish moss is extensively utilized for making mattresses and other cushions at moss "gins" at many places. The moss is cured by moistening and airing to decompose the living portion, then dried, carefully worked to remove dirt, sticks, and other undesirable materials, and thoroughly washed.

overflow by dikes. The soil is rich and mostly under cultivation in cane and other crops. Many scattered cypress trees remain in the swampy areas.

The extensive swamp lands in the Mississippi Valley in Louisiana are mostly useless for settlement without expensive diking, but they are valuable for growing cypress and other lumber. Some areas in the midst of the swamps that are high enough for cultivation are utilized for small farms, but even these are subject to overflow at times of high water.

Morgan City.
Elevation 18 feet.
Population 5,985.
New Orleans 80½ miles.

Morgan City, on the right bank of a baylike expansion of the Atchafalaya River, is a commercial and lumber center of considerable importance, as it has waterways of moderate depth into many parts of the cypress swamps as well as into the sugarcane country. The wide river here is the outlet of a series of large shallow lakes and numerous bayous occupying the area known as the Atchafalaya Basin. It receives the water of the Red River [13] mixed with some overflow water from the Mississippi River, which joins the Red River by way of the Old River near latitude 31°, 50 miles above Baton Rouge (130 miles above New Orleans). In the great flood of 1927 a large part of Morgan City was under water for two months.

Morgan City (originally Brashear, later renamed for Charles Morgan [14]) is near the head of tidewater and from 1850 to 1869 was the terminus of the railroad from New Orleans. At that time there were extensive boat connections in all directions by the rivers and bayous, and by way of the Gulf of Mexico to Galveston. The United States Government took possession of these communications during the Civil War. Charles Morgan, who had controlled most of the boat lines, purchased the railroad in 1869; it was extended west to Lafayette in 1880. Formerly the city's lumber business was extensive, but

[13] When the Mississippi River is low and the Red River is high the slope in the Old River is reversed and some of the Red River water flows through it into the Mississippi. No doubt the Red River flowed into the Mississippi River originally, but the gradual growth of a natural levee on the west bank of the big river forced the Red River to find an independent course to the Gulf down the channel now called the Atchafalaya River. This river and the Grand River have long been thoroughfares, and in earlier times many flatboats were used for freight transportation, going mostly by way of Plaquemine Bayou and locks to the Mississippi.

[14] Charles Morgan is regarded as one of the most important influences in the development of southern Louisiana. He was born in Connecticut in 1795 and died in New York City in 1878. He inaugurated various early coastwise steamship lines, mainly to places on the Gulf of Mexico, developed the railroad from New Orleans to Cuero, Tex., and dredged a steamboat channel through Atchafalaya Bay. In 1836 he founded a great iron works in New York, and in the same year he sent the first vessel from New Orleans to Texas, stopping at Galveston when that place consisted of one house.

now the principal occupations are agriculture, shipping crabs, and preparing shells for chicken feed and other uses. The shells are brought from the large reef of Pointe au Fer in Atchafalaya Bay, 30 miles southwest of Morgan City. One of the water routes of commerce in the region now is by the Grand River and a 7-foot canal through Plaquemine Lock, which enters the Mississippi River 20 miles below Baton Rouge.

The projected Intracoastal Waterway is to follow Bayou Boeuf into the Atchafalaya River at Morgan City and thence go westward through Wax Bayou.[15]

After crossing the Atchafalaya River over a long bridge the train reaches Berwick, a companion town to Morgan City and sharing with it the river trade and crab industry. In the region west of Berwick much of the land is under cultivation in sugarcane, but some woodland remains. An abandoned sugar mill (Glenwild) is conspicuous north of the railroad 3 miles west of Berwick.

Berwick.

Elevation 14 feet.
Population 1,679.
New Orleans 82 miles.

A typical small sugar plantation may be seen just north of the tracks 2 miles beyond Patterson (near Calumet siding), with groups of whitewashed houses for laborers and many very large, handsome moss-hung live oaks.

The principal outlet of Grand and Sixmile Lakes, at a point about 4 miles north of Patterson, is regarded as the beginning of the lower Atchafalaya River, and into it empties the famous Bayou Teche (Indian for Snake Bayou) at a point about 2 miles north of the town. This bayou originates far to the northwest. Running along the west side of the great alluvial valley of the Mississippi, it has built up a typical bayou ridge, 10 to 20 feet high, that is extensively settled and cultivated. The railroad is built upon this ridge from Patterson through Franklin, Baldwin, Jeanerette, and New Iberia, and in places the water of the bayou is visible from the train. With its many plantations, fine houses, luxuriant gardens, and handsome live oaks and pecan trees, it is one of the most interesting features in southern Louisiana. The bayou is a useful waterway, although at present the traffic is light.

Patterson.

Elevation 8 feet.
Population 2,206.
New Orleans 88 miles.

In early days the bayous and rivers were highways of travel to the Acadians and other settlers, who built their houses overlooking them.

[15] This waterway is being built by the Government to provide an inside channel along the coast from New Orleans to Corpus Christi (at a cost of $16,000,000) and, eventually, to the Rio Grande at Point Isabel. The bill passed by Congress in 1927 provides for a canal 100 feet wide to carry 9 feet of water. Many natural water bodies are to be utilized, some of them, however, requiring deepening and straightening. For much of its course it is from 10 to 20 miles south of the Southern Pacific lines.

The settlers used pirogues, or dugout canoes, and flatboats for transporting themselves and their produce from place to place, traveling by day only and camping on shore at night. Later on, in the French and Spanish régimes, every grantee of land was required to build a levee along the bayous and on top of it a road. Such was the origin of the Spanish trail from New Orleans to San Antonio that goes through Lafayette and of many other roads still existing in southern Louisiana.

There is a much used airport in the midst of the cane fields about 3 miles west of Patterson. Cane fields extend far westward up the "Teche country," with sugar mills at several places, including Shadyside and Bayou Sale. At Garden City a sawmill is in operation, using logs floated up Bayou Teche from the Grand Lake region.

Franklin, on the south bank of Bayou Teche, is an old commercial and sugar center, with large lumber and planing mills. Recently the operation of these mills has had to be discontinued, as the supply of cypress became exhausted or too remote.

Franklin.

Elevation 10 feet.
Population 3,271.
New Orleans 102 miles.

Louisiana is not usually regarded as an earthquake region, but it has experienced occasional quakes. The last notable event of the kind was the earthquake of October 19, 1930, the epicenter of which was in the Atchafalaya Valley between Franklin and Donaldsonville.

Baldwin is a local center of the sugar business and of a district in which various crops are raised on the Bayou Teche ridge and the slopes extending south. A branch railroad and a highway lead southwestward to the Cypremort sugar refinery and the great salt mine at Weeks Island (or Grande Côte). (See p. 21.)

Baldwin.

Elevation 13 feet.
Population 822.
New Orleans 106 miles.

In traveling across central-southern Louisiana the only visible features of geologic interest are the delta and bayou deposits, especially the mounds built by bayou and river overflow which have been referred to on previous pages. Farther west are the wide terrace plains of low altitude, floored by alluvial deposits of Recent age. It would scarcely be suspected that under this smooth cover there are formations which represent a long and complex geologic history. Many deep borings have revealed this subsurface geology to a depth of 8,000 feet or more. Below the Eocene beds is a great thickness of earlier Tertiary, Cretaceous, and older strata down to the crystalline rocks which underlie them. The principal formations so far recognized are listed in the following table:

Formations of Quaternary and Tertiary age underlying southern Louisiana

Age	Formation	Character	Thickness (feet)
Pleistocene.	Beaumont clay.	Clay and sand.	1,500+
	Lissie gravel.	Sand and gravel.	
	-Unconformity-		
Pliocene.	Citronelle formation.	Nonmarine; yellow and red sand and clay.	50-400+
	-Unconformity-		
Miocene.	Pascagoula clay.	Marine in part; blue-green and gray clay, some sand.	250-1,400(?)
	-Unconformity-		
	Hattiesburg clay.	Nonmarine; blue and gray clay, thin sand, and sandstone.	300-350
	Catahoula sandstone.	Nonmarine; gray sand, sandstone, fine conglomerate, clay.	600-800
Eocene.	Jackson formation.	Marine; gray sand and dark calcareous clay.	100-600
	Cockfield formation.	Palustrine; gypsiferous sand and clay with lignite.	400-800

Some recent estimates suggest that in the southern part of the area the Pliocene and later beds are 4,000 feet thick, the Miocene 4,000 feet, the underlying Tertiary more than 10,000 feet, and the Cretaceous possibly as much as 8,000 feet. This great succession of sediments indicates that the region was under water for a long time, during which a vast amount of material derived from the land was deposited. During this deposition the basin kept sinking much of the time, and doubtless the total amount of subsidence was fully 5 miles. There were also intervals of uplift when the land was above the water, a fact indicated by unconformities between most of the formations above listed. There is evidence that the region is still subsiding, for a few centuries ago cypress swamps were much more extensive than at present, as shown by the dead cypress on Cypremort Point and by the stumps of cypress in Weeks Bay, exposed at very low tide.

Southern Louisiana has had a somewhat complex fluviatile history, some of it decipherable from the resulting configuration or the distribution of deposits. Near New Iberia there are small areas of characteristic Red River deposits, which indicate that at no distant date the Red River drained south for a short time through Bayou Teche. Deposits of the latter stream overlying the low terrace plain southeast of New Iberia indicate that for a while this bayou overflowed its banks in the wide gap east of New Iberia and reached the Gulf between Avery Island and Weeks Island. (Howe.)

Jeanerette is an old and picturesque village named for an early French settler, Jean Erette, who operated a small corn mill. For many years the principal industry of Jeanerette was sawing cypress and other lumber brought from the swamps far to the northeast, but this activity has ceased because the sources of supply have become too remote. There is, however, considerable farming and dairying, and rice and cotton are produced. Formerly there were many small sugar mills in the vicinity, but only a few remain; one about 2 miles west of the town, on the bank of Bayou Teche, is conspicuous from the railroad.

Jeanerette.
Elevation 19 feet.
Population 2,228.
New Orleans 115 miles.

From Jeanerette northwestward the railroad follows the high south bank of Bayou Teche through cane fields and small woodlands. Throughout this district fine live oaks festooned with Spanish moss are conspicuous, many of them surrounding stately old homes. Among these are the Delgado-Albania plantation, on the bank of Bayou Teche, now owned by the city of New Orleans, and several other notable old estates, such as Bayside, Westover, Loisel, and Beau Pré, all surrounded by fine trees. About 5 miles west of Jeanerette, on the north bank of the bayou, is the livestock experiment station, 1,000 acres in extent, sustained by the cooperation of the United States Department of Agriculture and the State of Louisiana.

New Iberia, one of the oldest settlements in southwestern Louisiana, is a commercial and sugar center at the junction of several local railroads. Situated on the bank of the Bayou Teche, it has water communication with many places. It was incorporated as a town in 1839, and it is said that fully 80 per cent of the people are descendants of the Acadians.

New Iberia.
Elevation 20 feet.
Population 8,003.
New Orleans 127 miles.

These people originally were French settlers in Grand Pré, Nova Scotia (French Acadie), where they had lived for a century and a half before the English conquest in 1755. Then, when they refused to transfer their allegiance to England, their property, so industriously accumulated, was confiscated and they were deported. During the following decade many of them sought refuge in the French colony of southern Louisiana, where, however, they found conditions not entirely congenial, for Spain had just acquired control of that territory. But they were cordially welcomed, and many established themselves in the moist, fertile lands along the bayous, an environment far more agreeable than the rugged north country to which they had been accustomed. The effect of this propitious climate upon their character was diverse: some were content with a bare subsistence; others developed into landowners and men of affairs whose hospitality and graciousness were famous. Many descendants of the old Acadians remain, together with a large percentage of persons of French descent from the original New Orleans colonies. The local name for these people represents the defective pronunciation "Cajun." One group of Acadians that left the Mississippi at Plaquemine and came southwest through the swamps in 1757 found a small settlement at the present St. Martinsville, 9 miles north of New Iberia, where the newcomers were given tracts of land. Trappers, traders, and ranchers were scattered sparsely through the Teche country, and under the Spanish régime the settlement became a headquarters and finally a military post called the Poste des Attakapas (a-tak′a-pa). Four different flags have floated above it. Now, under the name St. Martinsville, it still has an Acadian population, dialect, and atmosphere, and these, together with its ancient structures, render it a most interesting place to visit. The region is perhaps most popularly known from Longfellow's narrative poem of the fair Acadian "Evangeline," the scene of which is laid principally on the Bayou Teche. At St. Martinsville is the heroine's grave, under the "Evangeline oak" in the yard of the church constructed in 1765, and various souvenirs of her life are on exhibition. In this headquarters of the old Acadian colony a monument in memory of Evangeline was erected in 1931, for she had become to the "Cajuns" the symbol of their early sufferings, their romance, and their faith.[16]

Eight miles south of New Iberia the hill known as Petite Anse, or Avery Island, rises prominently above the lowlands and marsh. Its height is 152 feet, and it is dimly visible from the railroad. It consists of a thumb-shaped mass of salt thrust up several thousand feet through the Coastal Plain deposits. The salt has been extensively mined for many years from a shaft about 200 feet deep, and great galleries, such as are shown in Plate 4, *B*, extend far underground in white salt. Borings 2,263 feet deep have not reached the base of the deposit. A feature of this kind is known as a salt dome, and its general relations are shown in Figure 1. Similar bodies of salt occur at the mounds constituting Jefferson Island, 8 miles west of New Iberia, and Weeks Island, 15 miles south of New Iberia, where also it is extensively mined for domestic use and for the manufacture of sodium chemicals. The production of salt at these localities has exceeded 7,000,000 tons, valued at more than $27,000,000,[17] and the supply is practically inexhaustible.

The three "islands" above mentioned and two smaller ones to the southeast occur along a line bearing N. 49° W., which probably marks

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[16] It is locally stated that Longfellow based his poem on the narrative of an old Acadian in St. Martinsville but modified it to have a different ending. The young woman referred to was Emmeline Labiche, and "Gabriel" was Louis Arceneaux, who told Emmeline that after waiting a long time for her to come he had given his promise to another. Demented by the blow, she wandered through the Teche region and finally died and was buried in the churchyard at St. Martinsville.

[17] Mineral Resources of the United States.

a narrow deep-seated zone of uplift or faulting that extends across the country for many miles. The movements along this line, especially at the domes, have continued into recent times. Owing to the uplift of the strata the domes reveal formations which in the adjoining region are concealed by alluvial deposits. At the surface there is more or less loam resembling loess, 10 feet or more thick, and in many places where this has been removed by erosion older gravel (Citronelle, p. 19) is exposed. On Avery Island there are small exposures of sandstone, clay, and lignite which may be of Pliocene or Miocene age.

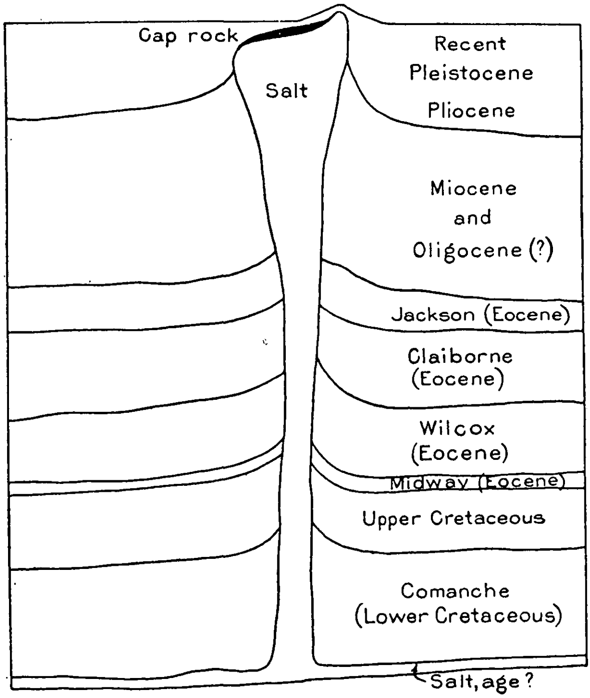


FIGURE 1.—Hypothetical section of salt dome at Avery Island, La. By H. V. Howe

In places here the beds dip 44°. The lignite, which is 18 feet thick, may have economic value.

At Jefferson Island there is a small mound only 75 feet high, but it has been found by recent boring that the area of doming is considerably larger, the salt core extending under Lake Peigneur; the depression in which the lake lies may be due to subsidence caused by the removal of salt by underground solution.

There have been several theories as to the origin of the numerous salt domes in the Coastal Plain of Louisiana and Texas, but most geologists regard them as due to the flow of the relatively plastic salt from a deep-seated stratum, to relieve stress in the earth's crust. The salt body has forced its way through the overlying sand and clay and to some extent domed and faulted the strata. The top of the salt core has risen to various heights in the different domes, but in one dome it is 6,400 feet below the surface. The domes near New Iberia above mentioned give rise to surface mounds of greater or less height, and the salt is near the surface, but in many salt domes the salt body lies deep and there is no topographic indication of its presence. Not long ago the only domes recognized were those which had surface manifestations, but exploration with the torsion balance and seismograph, instruments which detect the disturbances to gravity and to rock conductivity resulting from the uplift, has indicated the presence of many more, and drilling has verified their existence.[18] In some of the domes the disturbed strata surrounding and overlying the salt core serve as a reservoir for oil. The association of petroleum with many of the domes is believed to be due to a condition favorable for its migration and accumulation. About 80 domes are now known in the Louisiana-Texas Coastal Plain. More than two-thirds of them produce petroleum, with an aggregate of nearly 70,000,000 barrels in 1930, according to the United States Bureau of Mines. The sulphur and anhydrite occurring as cap rocks on most of the domes have resulted from secondary chemical reactions. The structure of a typical dome is shown in Figure 2, but there is considerable variety in character, form, and relations and in the depth to the top of the salt mass.

The easternmost is the Chacahoula dome, 3 miles north of Donner, discovered by seismograph exploration. Here the salt was penetrated in a test boring at a depth of 3,485 to 5,150 feet, where boring was stopped. No boring in these domes has passed entirely through the salt, although some holes have been drilled 4,000 feet in it.

The sandy loam exposed on Avery Island has yielded fossil shells of no very great geologic antiquity, and bones of the mammoth, elephant, buffalo, horse (*Equus complicatus*), *Mylodon*, and *Megalonyx*, all of which have been extinct for a long time (Howe). These deposits have been correlated with the Sangamon or third interglacial stage, indicat-

[18] A deeply buried salt mass has been discovered on the western margin of Lake Fausse Pointe, about 11 miles east-northeast of New Iberia. The only surface manifestations of the uplift were some gas emanations and paraffin in the soil, but a seismograph survey in 1926 showed the presence of a dome, and a boring found salt at 1,392 feet. Several borings found petroleum, the first one yielding 125 barrels a day from sands probably of lower Pliocene age lying at a depth of 1,062 to 1,143 feet, 100 to 200 feet above the salt core. The field attained a production of 16,800 barrels in 1927. The salt core is more than 2 miles in diameter and at one point comes within 823 feet of the surface. Another salt dome that underlies a small area about 6 miles east of New Iberia afforded a small production of petroleum in 1916–1920. Several borings in this dome that reached a depth of more than 3,000 feet are thought to have entered beds of Miocene age. The apex of this salt core comes within 805 feet of the surface. (Howe.)

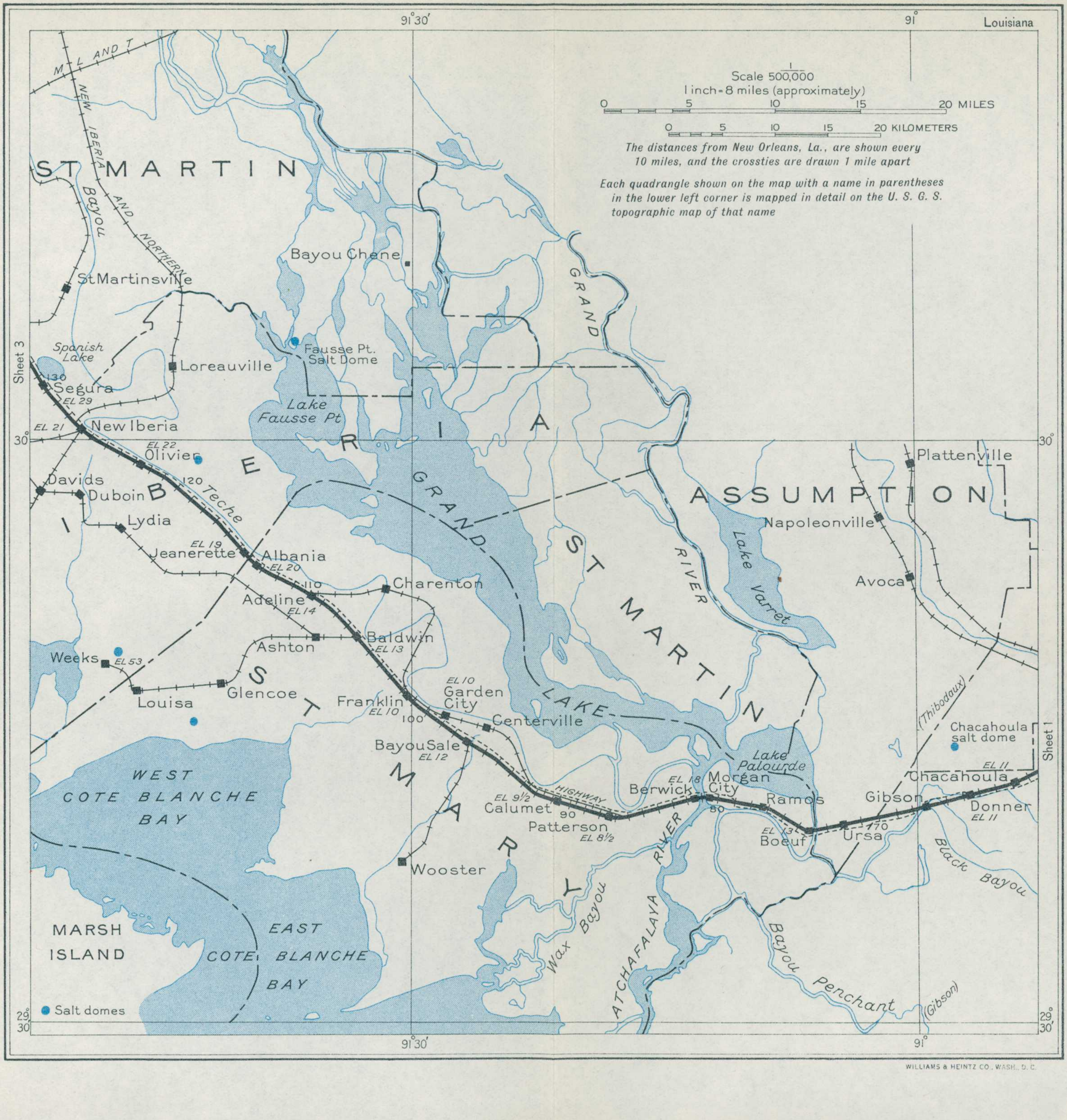
ing that Avery Island has stood above sea level since that time. Remains of man have been found associated with the bones, but paleontologists have not been fully convinced that they were contemporaneous.

The fact that the salt marshes stand above sea level indicates that Avery and the other islands can not be very old, for in such a moist climate reduction of the salt by solution would progress rapidly, although possibly the salt is rising at a rate to keep pace with solution. Although Avery Island and the other mounds rise but slightly above the general low plain and marsh, they have some notable characteristics of flora, due mainly to soil differences, and also some peculiarities of animal and insect life.

A sanctuary for herons and other birds, established on Avery Island in 1894, is locally estimated to give refuge to over 100,000 herons, the same birds returning year after year. Some of the birds are labeled, and a record is kept of their zones of migration. Many wild fowl winter in Louisiana, but the draining of wet lands has diminished their former plentiful food supply, so that now large numbers of birds move on to Central America and Mexico. Myriads of blue geese come from their breeding grounds in Baffin Land to spend the winters in this region. As the number of birds has decreased, the sale of wild birds has been made illegal, and the hunting season and the bag limit are much reduced. On Avery Island also is a large arboretum in which a great variety of semitropical plants have been assembled.

On this island is manufactured the famous tabasco sauce, a fiery but savory essence of a special pepper imported from Mexico, which thrives in the warm climate of this region; many of these peppers are also dried and ground for flavoring. The cultivation of this pepper and the bottling and shipping of the sauce give occupation to many persons living near New Iberia. Another special industry here is a paper mill in the east edge of the town that utilizes rice straw, a material which is largely wasted under ordinary conditions of harvesting. Considerable sugarcane is raised near New Iberia, and corn and vegetables are grown.

One of the most noticeable topographic features in the vicinity of New Iberia is the northward-facing margin of the Hammond terrace, 10 to 15 feet high, which extends northwestward from that place. It is ascended by the railroad a short distance west of New Iberia. Beyond Segura it forms the south bank of Spanish Lake, on some maps called Tasse Lake, which lies between it and the natural levee that Bayou Teche has built up. To the west it merges into the general upland which lies west of the lowlands of the Mississippi Valley.


Louisiana
Scale 1/500,000
1 inch = 8 miles (approximately)
0 5 10 15 20 MILES
0 5 10 15 20 KILOMETERS
The distances from New Orleans, La., are shown every 10 miles, and the crossties are drawn 1 mile apart
Each quadrangle shown on the map with a name in parentheses in the lower left corner is mapped in detail on the U. S. G. S. topographic map of that name
ST MARTIN
IBERIA
ST MARTIN
ST MARY
ASSUMPTION
GRAND LAKE
GRAND RIVER
ATCHAFALAYA RIVER
WEST COTE BLANCHE BAY
EAST COTE BLANCHE BAY
MARSH ISLAND
Bayou Teche
Bayou Chene
St Martinsville
Spanish Lake
Fausse Pt. Salt Dome
Lake Fausse Pt
Loreauville
Segura
New Iberia
Olivier
Davids
Duboin
Lydia
Jeanerette
Albania
Charenton
Adeline
Baldwin
Ashton
Weeks
Glencoe
Louisa
Franklin
Garden City
Centerville
Bayou Sale
Calumet
Patterson
Wooster
Berwick
Morgan City
Ramos
Boeuf
Ursa
Gibson
Donner
Chacahoula
Chacahoula salt dome
Plattenville
Napoleonville
Avoca
Lake Verret
Lake Palourde
Wax Bayou
Black Bayou
Bayou Penchant
(Thibodaux)
(Gibson)
M L AND T
NEW IBERIA AND NORTHERN
HIGHWAY
Sheet 3
Sheet 1
Salt domes
91°30'
91°
30°
29°30'
WILLIAMS & HEINTZ CO., WASH., D. C.

Just east of Lafayette the terrace step is only about 12 feet high, but at Opelousas, 25 miles northwest, its steep eastern face is a bluff nearly 40 feet high. Its elevation is 35 feet near Rayne and for some distance beyond. The land is better drained than the lowlands of the valley of the Mississippi or the low prairies to the south, and it contrasts also in having a slightly rolling configuration and sandy soil. Refugees of the flood of 1927 went to this upland near Segura as the nearest highland that was available. At the crest of this flood the swamp lands to the north were under 5 to 10 feet of water, and even New Iberia was inundated for several days. This flood was the first in a century that overflowed any of the country south of Bayou Teche.

Southeast of New Iberia there is a terrace or upland somewhat similar to the Hammond terrace, lying south of the Bayou Teche mound and extending to and beyond Jeanerette. South of this terrace is a lowland flat that extends as far to the west as Vermilion and Mermentau Prairies, which are mostly less than 20 feet above sea level. (Turn to sheet 3.)

An important resource of southwestern Louisiana is underground water, which yields flowing wells at moderate depth in the lower lands and water available for pumping in the higher areas. The wells are mostly from 200 to 300 feet deep and obtain their supplies from gravel and sand in the younger formations.

Cade.
Elevation 32 feet.
New Orleans 134 miles.

At Cade is the junction with a branch railroad which goes to Port Barre, a small town on Bayou Cortableau about 40 miles north. The first station north of Cade on this branch line is St. Martinsville, above referred to in connection with the legend of Evangeline. Cade is surrounded by cane fields, and considerable quantities of cane and other farm products are shipped here and at Burke and Duchamp sidings.

Broussard.
Elevation 37 feet.
Population 806.
New Orleans 140 miles.

At Billeaud, a mile east of Broussard, a large sugar refinery just north of the railroad utilizes cane from the adjoining region. Broussard is an old town sustained in large part by the sugar industry and surrounding farms. It was named for a French captain by one of his descendants when the town was established after the Civil War. The rolling country is covered with cane fields that extend at intervals to Lafayette, where they give place to rice. Much pepper also is raised.

152109°—33——3

The region hereabouts is called the Attakapa country, from the Indians who originally occupied it, of whom now a very few known descendants remain near Grand Lake. They were nearly annihilated by neighboring tribes, notably the Choctaws, at a battle on a hill about 3 miles east of Billeaud, just before the white settlers came into the country. Many of their burial mounds occur along the banks of Bayou Teche, and their weapons and utensils are found occasionally.

Lafayette.
Elevation 39½ feet.
Population 14,635.
New Orleans 146 miles.

Three miles northwest of Broussard the railroad crosses the Vermilion River near the place where the first settlement was made in this region. It was located at the head of navigation and was of considerable importance as a trading post under the successive names of Little Manchac, Pinhook, Vermilionville, and Lafayette. Here also in 1863 occurred an important battle of the Civil War when the Union troops moved through the Teche country and established a camp at Lafayette. Lafayette, in the heart of the Attakapa country, has nearly doubled its population in a decade, owing to its advantages as a railroad and general commercial center. A branch railroad runs to Alexandria, on the Red River. The mean annual temperature here is 65°; the average for July is 81° and for January 52°. Lafayette is the westernmost of the old French towns, and many descendants of French settlers are included in its population. In the southern edge of the town is the Southwestern Louisiana Institute. On exhibition at the railroad station is the first locomotive used on the Morgan Line, the predecessor of the Southern Pacific in this section. It contrasts strongly with modern locomotives.

According to the United States census, in 1929 Lafayette Parish produced 18,394 bales of cotton, 135,524 bushels of rice, 146,246 tons of sugarcane, 45,027 pounds of figs, 166,045 bushels of sweetpotatoes, 14,144 bushels of Irish potatoes, 14,262 bushels of soybeans, and 505,445 bushels of corn. Oranges and pecans are also produced.

There is a salt dome at Anse La Butte, 5 miles northeast of Lafayette, but holes drilled in it to a depth of 3,400 feet found only a small amount of petroleum.

From Lafayette the railroad goes due west for 16 miles to and beyond Rayne over wide prairies with an average elevation near 35 feet. Three miles west of Scott siding the Bayou Queue de Tortue (French, tail of a tortoise) is crossed. Rice fields soon begin to be conspicuous, especially near Duson, a siding named in honor of a Canadian refugee settler of early days.

Rayne.
Elevation 36 feet.
Population 3,710.
New Orleans 160 miles.

The village of Rayne is in an important agricultural community, with its chief interest in rice, which is raised over a wide area in the vicinity. The fields are irrigated by water pumped from bayous and wells. The Southern Pacific Railroad here crosses a branch of the Texas & Pacific Railway which connects Opelousas and Crowley.

Crowley.
Elevation 24 feet.
Population 7,656.
New Orleans 168 miles.

Crowley, the parish seat of Acadia Parish, is now the center of the great rice industry of southwestern Louisiana. About three-fourths of the area of the parish is in rice, which is irrigated by 300 miles of canals and water from 125 wells. The principal supply of underground water here is found about 300 feet below the surface, and considerable water is also obtained at depths of 17 to 60 feet. One of the large canals is crossed between Rayne and Crowley. It is claimed by local authorities that one-third of the rice produced in the United States is raised within 30 miles of Crowley. Acadia Parish alone produced 16,317,463 bushels of rough rice in 1929 (Fifteenth Census). There are many rice mills where the rice is cleaned and polished, with an annual production averaging 1,500,000 barrels of 162 pounds, according to the Crowley Chamber of Commerce. Rice is milled to cull out broken and small material and remove the hull and the several thin layers that surround the grain, a process which robs it of valuable food elements. Most of the rice to be exported has to be coated with a very thin film of talc in glucose. A large part of it is shipped to Puerto Rico. Rice requires a generous supply of water, not only for the growth of the rice plant but to kill weeds that would otherwise choke it. This water is pumped from wells and bayous and in large amount from the Sabine River. Many of the canals and ditches that bring the water, some of them from long distances, are crossed by the railroad. Fortunately, in most seasons there is an abundant water supply, but it is found that in some bayous strong pumping causes the backing up of brackish water, which is deleterious. The pumping is done by steam and electricity, with oil for fuel, and most of the water is supplied by companies that irrigate their own fields and sell water to others. Some of the batteries of pumps require from 400 to 800 horsepower. The fields are crossed by a network of small ditches like furrows, with low banks to retain the water.

Ordinarily the irrigation of rice costs about one-fifth of the value of the yield, which is 40 to 50 bushels to an acre. Rice sprouts in two or three weeks after planting and soon grows to 8 to 12 inches, when it is flooded until practically mature.

The extensive cultivation of rice in this region is relatively modern, dating back to 1894 and 1895, when the first large pumps were introduced near Crowley. The early Acadians planted small areas of rice along the lowlands and in various dammed areas, but the drainage of all these tracts was difficult in wet weather, and the crops failed in dry years.

From Crowley a railroad runs north, serving the rice country as far as Alexandria.

Estherwood.
Elevation 19½ feet.
Population 40.*
New Orleans 173 miles.

Just west of Estherwood a wide ditch is crossed which carries water for the irrigation of the extensive rice fields in the neighborhood. Most of the prairie land is utilized for this crop, but narrow wooded strips remain along the streams.

Midland.
Elevation 18 feet.
Population 80.*
New Orleans 176 miles.

At Midland are branch railroads, one going north to Eunice and Mamou and the other south to Gueydan and Abbeville. The old village of Mermentau, with a quaint ancient graveyard on its main street, is built on the east bank of the Mermentau River. This stream, resulting from the confluence of Bayou des Cannes and Bayou Nezpique, is bordered by swamps in which many cypress trees remain with their festoons of Spanish moss. It empties into Lake Arthur, 15 miles south, a famous resort for hunting ducks and geese and for fishing. There is a local tradition that the vessels of the pirate Lafitte (see p. 13) made a practice of ascending this river to sell stolen slaves.

Mermentau.
Elevation 17 feet.
Population 394.
New Orleans 181 miles.

Jennings.
Elevation 29 feet.
Population 4,036.
New Orleans 186 miles.

Jennings, the parish seat of Jefferson Davis Parish, is a local headquarters for rice and other agricultural products. The rice crop in this parish was 4,717,628 bushels in 1929, according to the census returns, which showed also 182,439 bushels of corn and 4,185 bales of cotton. A very special industry is the extensive cultivation of Bermuda or Easter lilies, which are shipped from this place all over the United States. The pretty town is built on a low, flat ridge between the valleys of the Mermentau River and Bayou Chene, in a region of wide prairies with many rice fields.

Five miles northeast of Jennings is the productive Jennings oil field, which obtains petroleum from a sharp local doming of the strata. The derricks are not visible from trains owing to timber along Bayou Nezpique. They are shown in Plate 5, *A*. This field has been described by Barton and Goodrich. It was one of the earliest oil developments on the Gulf coast, having given its first manifestation of oil eight months after the strike at Spindletop in 1901. In 1906 the field had a production of more than 9,000,000

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barrels, but finally the amount diminished, and the yield in 1930 was only 527,834 barrels. It is estimated that in all about 40,600,300 barrels has been produced from an area of about 300 acres, which is a larger production than that of any other field in Louisiana. Some of the borings found considerable gas. Salt was reached at a depth of 3,716 feet, but most of the oil was obtained at 1,700 to 2,000 feet.[19] For several years the oil from this field sustained a refinery at Jennings.

Southwest of Jennings, between the railroad and the Gulf of Mexico, are noted hunting and fishing grounds with a great variety of fish and wild fowl.

A short distance beyond Jennings, just before crossing Bayou Chene, the railroad turns due west, a course which is continued 50 miles to Edgerly, over prairies with an average elevation of 20 feet. While many parts of the region are under cultivation for rice, other crops are raised, including considerable cotton. There are many cattle in the numerous pastures.

Welsh.
Elevation 23 feet.
Population 1,514.
New Orleans 197 miles.

Three miles west of Welsh there is another low local dome, known as the Welsh oil field, the derricks of which are mostly about a mile north of the railroad. About 90 wells have been drilled here, and some of them yielded a small production for a few years. Much of the oil was used for lubrication on the locomotives of the Southern Pacific lines. (Turn to sheet 4.)

Just beyond Welsh the railroad crosses the east branch of Bayou Lacassine, the water of which is used to some extent for rice irrigation; the west branch of this stream is crossed just east of Lacassine siding. A short distance west of that siding there is a small clump of pines south of the railroad, a sporadic outlier of the great pine forest that covers a large part of western Louisiana and eastern Texas. Not far beyond this place the Missouri Pacific Railroad is crossed.

In this region "pimple mounds" appear in the prairies, and they become more numerous toward Lake Charles and beyond, though somewhat scattered. Most of them are less than 3 feet high and approximately circular. A few of the larger well-formed mounds are very conspicuous and reach 75 to 100 feet in diameter. Many of them have been more or less obliterated by cultivation, and some have been cut by drainage ditches and road grading. They occur

[19] The subsurface geology (see table, p. 19) showed clay (Beaumont) to 90 feet; sand (Lissie and Citronelle), 90 to 1,100 feet; clay, mainly Pascagoula and Hattiesburg(?), 1,100 to 2,800 feet; and sand (Catahoula), 2,800 feet to an unknown depth. Probably Jackson strata were penetrated in the deeper holes, several of which were from 7,294 to 7,447 feet deep. One dry hole 8,903 feet deep was abandoned in hard blue shale regarded by some geologists as Oligocene.

at intervals far into eastern Texas and over a wide area in the region north. Their origin is unknown, although many theories have been advanced to account for them.

Lake Charles.

Elevation 16 feet.
Population 15,791.
New Orleans 220 miles.

The city of Lake Charles is attractively located on the wooded shores of Lake Charles, a broad expansion of the Calcasieu River, one of the principal streams of southwestern Louisiana (formerly called the Rio Hondo). The name Calcasieu is derived from that of an Indian tribe which once occupied the region and is now represented by a few descendants living in the northern part of Calcasieu Parish. This river, which is crossed west of the town, was the resort of slavers in the early days when the region west to the Sabine River was neutral territory between Mexico and the United States. The name of the city is taken from the lake, which was named for Joseph Charles, an old settler. This city is the farthest inland of the Gulf ports, being 75 miles from the coast, with which it is connected by a 30-foot channel dredged through the river, Calcasieu Lake, and Calcasieu Pass, at the joint expense of the parish and the United States. This channel has no tide and no locks. The harbor basin has accommodations for all classes of ocean vessels, by which it ships more rice than any other port in this country. One of the three large mills in the city manufactures cellulose from rice hulls and is said to be the only plant of its kind in the world. Considerable cotton is raised near by, and lumbering is an important industry.

In the marshlands of Cameron Parish, south of Lake Charles, are two isolated domes, the Hackberry and the East Hackberry, which produce a large amount of petroleum. The latter was discovered in 1926 by means of seismograph survey in a region where there are no surface indications of geologic structure. The oil is derived largely from sand of Miocene age [20] at a depth of 3,900 feet, but oil is also produced from sand over the "cap rock," which lies about 2,955 feet below the surface. One 6,995-foot hole is in shale of supposed Jackson (Eocene) age. From 1927 to the end of 1930 a little more than 4,000,000 barrels of oil was produced from 50 wells in this district, according to the United States Bureau of Mines.

Lake Charles is about at the eastern margin of the great pine belt which extends westward to and beyond Beaumont, Tex., and far to the

[20] The subsurface geology of this part of Louisiana as revealed by borings is as follows: Recent marsh deposits of much sand and clay, about 50 feet; sand and gravel of the Beaumont formation (350 feet) and Lissie formation (650 feet); a thick succession of blue sandy silt, blue and gray silty sand, clay, blue-green shale, and some clean sand, mostly fine grained, representing the Pliocene and Miocene, 5,000 feet or more; older Tertiary gray silty sand, sandy shale, and hard gray shale, 500 feet or more. These beds are underlain by heavy shale believed to be of Jackson age. (Bauernschmidt.) (See also table, p. 19.)

north; for much of the distance between these two places the railroad skirts its southern border. Originally there were large forests of fine timber in this region, but much of the pine has been cut.

In the great marshes between Calcasieu and Sabine Lakes, southwest of Lake Charles, is a muskrat "ranch," 29 miles long by 14 miles wide, comprising 170,000 acres and having 70 miles of canals. Here a large number of pelts of this animal are obtained every year. The region is also famous for hunting and fishing. Water hyacinths grow in picturesque abundance in its many ponds and bayous.

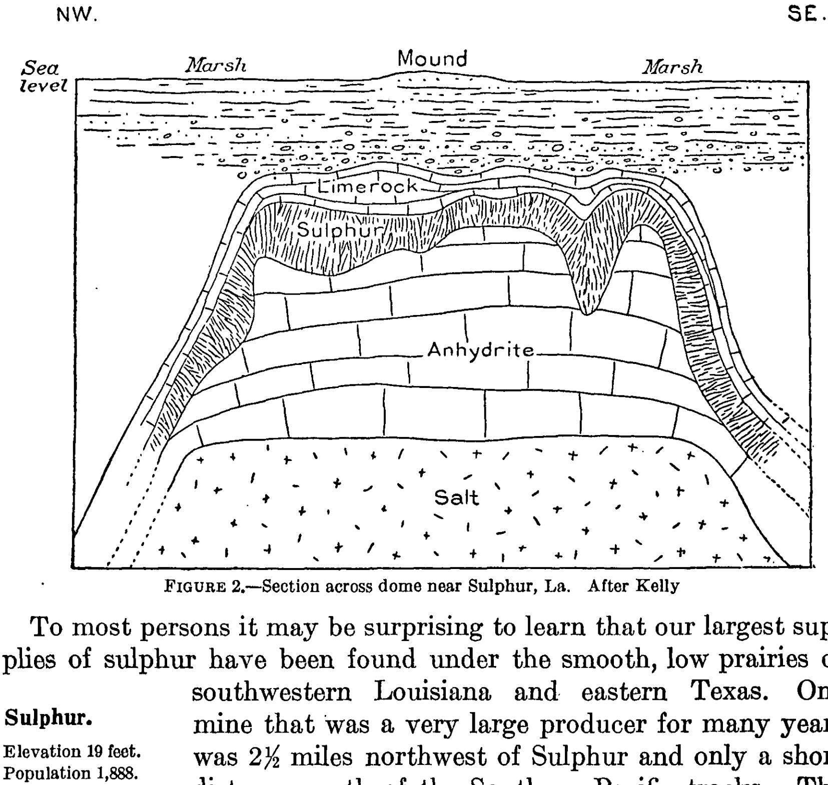

FIGURE 2.—Section across dome near Sulphur, La. After Kelly

Sulphur.
Elevation 19 feet.
Population 1,888.
New Orleans 230 miles.

To most persons it may be surprising to learn that our largest supplies of sulphur have been found under the smooth, low prairies of southwestern Louisiana and eastern Texas. One mine that was a very large producer for many years was 2½ miles northwest of Sulphur and only a short distance north of the Southern Pacific tracks. The total production here exceeded 10,000,000 tons and had a gross value of more than $150,000,000 (Kelly). The sulphur is now exhausted. The mineral occurred in the anhydrite cap of a circular, flat-topped salt dome of small extent, 75 acres in all, where it had accumulated through chemical reaction for a very long period. The relations are shown in Figure 2.[21] The sulphur was discovered in

[21] The overlying material consists of about 250 feet of yellow and red clay alternating with sandy clay and sand (Beaumont clay) and gravel (Citronelle formation) to the cap rock. The sulphur is thought to have been derived from the reduction of the calcium sulphate of the anhydrite, an origin indicated by the fact that the volume of sulphur and limestone (calcium carbonate) was found to increase in proportion to the decrease in calcium sulphate.

a 1,230-foot boring for petroleum, of which a small surface seep had long been known, the black ooze being used by early settlers for axle grease. The first attempts at mining were made by a French company, which planned to use a huge iron caisson shipped in sections from France, but the enterprise failed after the expenditure of nearly a million dollars. One of the rings of this caisson still lies on the bank of the Calcasieu River, with a pine tree 2 feet in diameter growing through it. After several other vain attempts to mine the sulphur, the Frasch process [22] was developed in 1903; by this process the sulphur was melted in place by steam, pumped to the surface in liquid form, and stored in great vats until needed. (See pl. 6, *B*.) In this way the sulphur accumulated in solid blocks 1,000 feet long, 500 feet wide, and 50 feet high, from which it was easily broken for shipment. Since 1919 the great deposits of sulphur at Gulf, New Gulf, and other places in Texas have become the chief source of our commercial supply, with reserves of many millions of tons. Recent drilling on the Sulphur dome has developed an oil field which in 1930 had a production of 1,351,195 barrels from 33 wells.[23]

There are extensive rice fields interspersed with swamps and forests about Sulphur and in the region west, notably about Edgerly and Vinton.

Edgerly.
Elevation 23 feet.
Population 150.
New Orleans 238 miles.

Just south of Edgerly conspicuous oil derricks mark the occurrence of petroleum in another structural dome under the level lands of the region. Strong surface indications of gas and oil at this place were noted at an early time, but drilling did not begin until 1907. The first holes were not successful, but after repeated attempts considerable oil was obtained at depths of 2,300 to 3,100 feet from beds of supposed Pliocene age. Salt found at a depth of 4,000 feet shows that a salt dome is present far underground. The oil is heavy (19° to 22½° Baumé) and when refined makes a fine lubricating oil (Minor). The field reached its peak production of 1,688,862 barrels in 1915; there has been a great decrease in recent years, the production in 1930 being only 142,380 barrels.

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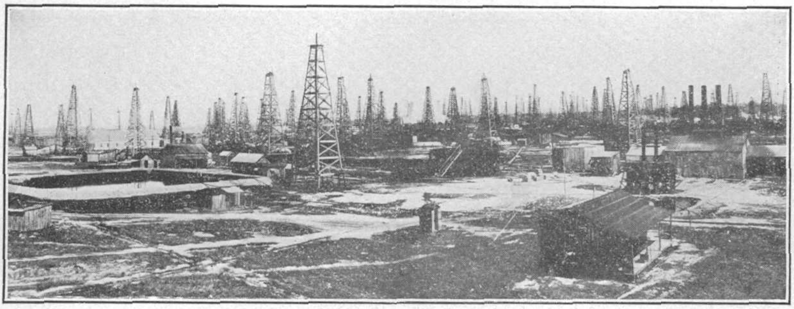
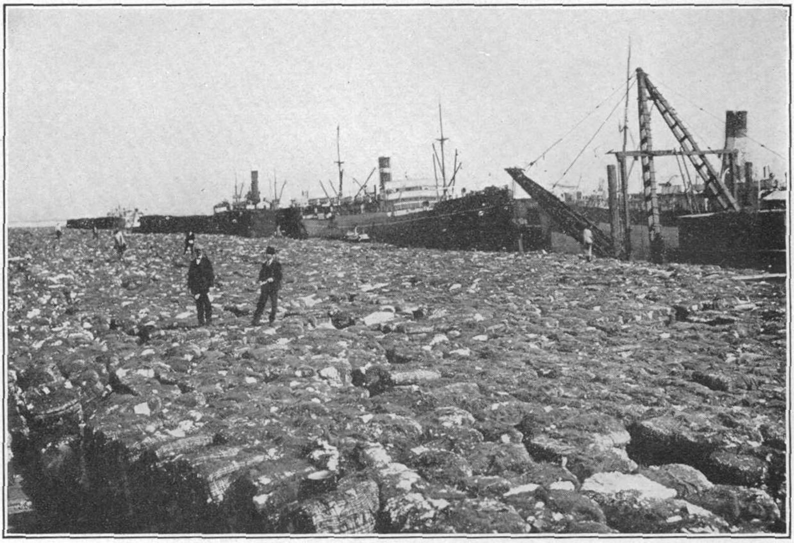
[22] This ingenious method of obtaining sulphur from deep underground deposits was perfected by Hermann Frasch in 1891 after many years of experimentation. A hole is drilled deep into the deposit, which is mostly a mass of honeycombed limestone filled with sulphur. Into the hole three concentric pipes are placed with perforations at their ends; through the outside pipe superheated steam (300°) is supplied, which melts the sulphur. The central and somewhat longer pipe conveys hot compressed air, which so lightens the liquefied sulphur that it is forced to the surface by the combined air and steam and water pressure. The heat of the steam and water in the outer column and in jacketed pipes on the surface keeps the sulphur melted while it is conveyed to vats built up with wooden walls to the requisite height.

[23] South Louisiana Oil Scouts Assoc. Bull. 1, 1930.

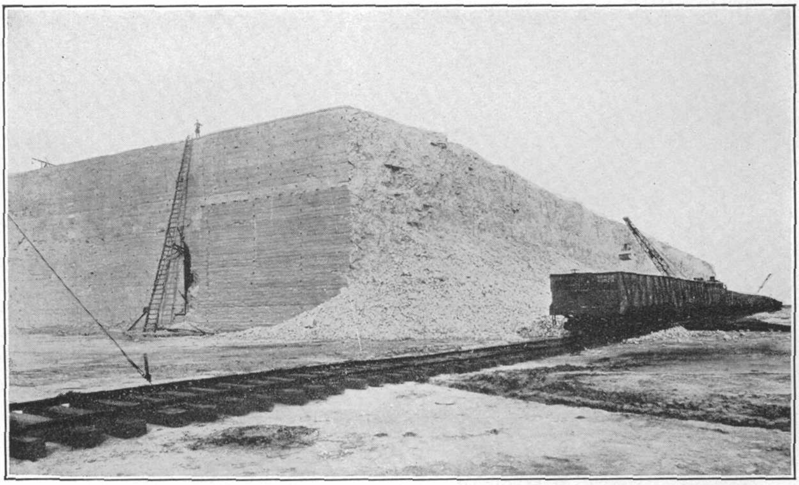


A. OIL FIELD NEAR JENNINGS, LA., IN 1928
Total production more than 40,000,000 barrels from 504 wells.

B. PART OF GALVESTON, TEX.
General view from an airplane. Shows the sea wall.



A. COTTON READY FOR SHIPMENT, GALVESTON, TEX.
19,000 bales.



B. BLOCK OF SULPHUR AT NEW GULF, TEX.
Ready to be broken up for shipment.

About 3½ miles southwest of Vinton is a typical Gulf coast salt dome yielding petroleum, the first dome discovered with oil on its flanks. The dome makes a low mound at the surface with a lake in the center and has a salt core about a mile in diameter. It was looked upon as a likely source of petroleum, especially as it had oil and gas seepages on its summit, and some oil had been obtained in shallow wells near by. Drilling began in 1901, resulting in finding traces of oil, but it was not until 1910 that a large production was developed; in the next few months more than 2,000,000 barrels of oil were produced. Production declined later, and now it is confined to some old wells, which are pumped. The total production to the end of 1930 was 34,317,000 barrels from an area of 150 acres, mostly from a depth of 2,200 to 2,300 feet.[24] The salt lies at a depth of 925 feet, with a 500-foot cover of "cap rock" limestone. The deeper borings penetrate the Jackson (Eocene), with the Oligocene pinched out by the salt on the west and southwest sides of the dome. The oil ranges in gravity from 19° to 37° Baumé, the latter coming from a sand at 3,385 feet. The producing sands are regarded as Miocene and possibly Oligocene. (Thompson and Eichelberger.)

Vinton.
Elevation 16 feet.
Population 1,989.
New Orleans 243 miles.

From Vinton the railroad follows the crest of a long low ridge southwestward to Toomey, where it curves to the west to cross the Sabine River. For nearly 200 miles this river is the boundary line between Louisiana and Texas; it empties into Sabine Lake 8 miles below Orange. North of the railroad crossing the river is navigated only by small craft, but many logs are floated down it, and the water volume is large in times of freshet. No precise survey has yet been made of its tortuous course, most parts of which are bordered by swamps. Much of its water is pumped for the irrigation of rice fields.

After crossing the Sabine River into Texas the railroad makes a great curve to the south.

The State of Texas is the largest of the United States, measuring 772 miles from east to west and 723 miles from north to south. It has an area of 265,896 square miles, or 7.2 per cent of the United States. It is larger than France and than the States of Pennsylvania, New York, Ohio, Virginia, and all of New England combined. A diagonal across the State from Texline to Brownsville is 1,107 miles long, and the length along the Southern Pacific Railroad across the State is 940 miles. The Rio Grande is its southwestern boundary for nearly 800 miles, and there is 400 miles of shore line along the Gulf of Mexico.

Texas.

The population in 1930 was 5,824,715, or nearly as much as that of Massachusetts and Connecticut combined, an increase of about 25 per cent in 10 years. In 1836 the Anglo-American population of

[24] South Louisiana Oil Scouts Assoc. Bull. 1, 1930.

Texas was probably less than 30,000. Ten years later it was 100,000, with 35,000 slaves. The density of population is now 22.2 to the square mile. The largest city is Houston, with a population of 292,352, and the other large cities in order of size are Dallas, San Antonio, Fort Worth, and El Paso. The population includes about 20 per cent of persons regarded as "Mexican," most of whom live in the southern part of the State, and every season many laborers come from Mexico to assist in harvesting cotton and other crops.

Texas has vast agricultural interests, for, according to the census reports for 1930, nearly 75 per cent of its land area is in farms or ranches, which, with buildings and machinery, are valued at $3,779,593,795. Among the principal items of production in 1929 were rice, 5,158,544 bushels (from 105,616 acres); hay, 650,992 tons; and cotton, 3,793,392 bales (500 pounds each), or 40 per cent of the cotton produced in the United States. In 1926, a record year, the cotton crop was 5,620,831 bales. In 1929 vegetables valued at $14,125,151 were produced, and grains other than rice 217,000,000 bushels. The aggregate value of agricultural products in 1929 was more than $1,000,000,000. The production of grapefruit in 1929 was 997,551 boxes, but as yet only one-third of the trees are productive. Although most of the great ranches of former days have been subdivided, the number of cattle in the State in 1930 was 6,602,702 head, and of sheep and goats, 10,163,655 head.[25] In 1929 the wool and mohair clip was 50,302,601 pounds, valued at $16,636,096; 4,726,363 pounds of honey was produced; the fig crop was 8,425,468 pounds; peanuts, 2,290,000 bushels; and pecans, many of them from cultivated trees, 9,588,376 pounds. Pecan trees, some of them 3 feet in diameter, grow wild in most parts of central and eastern Texas. According to the Texas Almanac, Texas ranks seventh among the States in lumber production, with a cut of 42,000,000,000 board feet in 1910–1930, not counting poles, posts, ties, and unrecorded wood for local use.

Texas leads in sulphur production, having shipped in 1930, according to the United States Bureau of Mines, 3,372,338 tons, valued at $30,841,065, or between 80 and 90 per cent of the world output and 97 per cent of the output of the United States. This mineral comes from the Gulf coast region not far west and southwest of Houston. The petroleum output was 296,876,000 barrels in 1929 and 290,457,000 barrels in 1930, and a large amount of natural gas was utilized. Much of the petroleum is produced in the portion of the Gulf coast region traversed by the Southern Pacific Railroad. Extensive deposits of lignite occur, also some bituminous coal, of which in all about 1,000,000 tons is mined annually. The cannel coal of Santo Tomas, in Webb

[25] Many of the goats are Angoras, which yield a clip of 3 to 8 pounds each. The first ones were introduced in 1849, a gift from the Sultan of Turkey.

County, is, according to Ashley,[26] the largest body of cannel coal of bituminous rank in the United States. A large percentage of the product is used at Fort Sam Houston in San Antonio. Considerable iron ore is available, and there are many minor mineral deposits of value. Helium from bore holes near Amarillo is an important product, and potash exists in the northwestern part of the State.

According to the Texas Almanac, Texas is second only to New York in the value of exported materials originating in the State, which in 1929 had a value of $657,559,600. The total exports, of which about two-thirds were shipped from Galveston, were valued at $834,000,000.

When Texas was admitted to the Union it retained its public lands, which, with the exception of large areas reserved for the benefit of the State university and schools, have since been disposed of. Many square miles were donated to aid railroad construction, and the last 3,000,000 acres in the "Panhandle" defrayed the cost of the construction of the State capitol. A large revenue has come to the State university from the discovery and production of petroleum on the university lands. Texas public lands were divided into areas of various sizes and shapes, some of them in units of 1 square mile, called sections and many of them in irregular areas mostly measured in varas.[27]

With its great area and variation in elevation, Texas presents many differences in climate, ranging from semitropical in the lowlands at the south to temperate in the highlands at the west. The rainfall is heaviest in the eastern part of the State, where the mean annual precipitation exceeds 50 inches. (See pl. 1.) There is a gradual diminution westward along the Southern Pacific line to 30 inches near the longitude of San Antonio, 20 inches near longitude 101°, and from 10 to 20 inches in most of the western part of the State, some portions of which are decidedly arid. The rain in eastern Texas comes largely from the Gulf of Mexico and falls most abundantly in the winter; that in the western part falls mostly in heavy showers in summer. Most of the country south of the latitude of San Antonio has a mean annual temperature of 70° or more, approaching 75° in the southern counties. In the high plains region the mean annual temperature is in general less than 60°, and the winters, although usually short, are decidedly cold.

The history of Texas is full of interest. It is believed that the first white man to reach the region was Cabeza de Vaca, a member of the expedition of Pánfilo Narváez, who sailed from Spain in 1527 to occupy a royal grant in Florida but, disappointed in its character,

[26] Ashley, G. H., U. S. Geol. Survey Bull. 691, p. 251, 1919.

[27] A vara is an old Spanish unit measuring 33⅓ inches. The old league of 5,000 varas is very nearly 2⅔ miles. A square league is called a sitio (4,428.04 acres), and 5 sitios make an hacienda.

set out for Mexico and in 1528 was shipwrecked on the coast somewhere between Matagorda and Galveston. The five survivors were held captive by the Indians, but De Vaca and a negro, Estevan, finally escaped, and after several years of wandering, probably across south-central Texas and the Edwards Plateau, crossed the Rio Grande into Mexico somewhere between Presidio and El Paso, and finally reached San Miguel de Culiacan (me-gale′ day coo-leea-can′) in 1536. Francisco Vásquez de Coronado crossed Texas in 1541 on his expedition to Quivira, and Antonio de Espejo explored a part of the Pecos Valley in about 1582. He was followed by Gaspar Castaño de Sosa in 1590. The oldest settlement is Ysleta (ees-lay′ta), near El Paso, which began as a settlement of Tiguex Indians established there by Gov. Antonio Otermín, whom they had accompanied from Isleta, N. Mex., whence he fled during the Pueblo uprising of 1680. The first white settlement in the State was a short-lived French colony set up by René Robert La Salle in 1685 near Matagorda Bay, which he mistook for the mouth of the Mississippi. The first missions were established in 1690 and 1716–17 in eastern Texas, in the general neighborhood of Nacogdoches, among the Tejas Indians, but they were built of perishable materials and in time were completely obliterated. Alonzo de León and Padre Damian Massanet, who founded the missions in 1690, came from Coahuila, Mexico, into central Texas and discovered and named the Nueces (nway′sace), Hondo (own′do), Leon (lay-own′), Guadalupe (gwa-da-loo′pay), and other rivers. They brought a party of 88 soldiers and friars, 12 muleteers, 13 servants, 720 horses and mules, 82 pack loads of provisions, and 3 pack loads of presents for the Indians.

San Antonio, the capital city during nearly the whole era of Spanish and Mexican rule, was started by the Spanish Government as a presidio in 1718, primarily as a bulwark against the French. The missions near by were begun soon thereafter, some of them having been transferred from other localities. Difficulties with the Indians finally led to the abandonment of all settlements except San Antonio, Goliad, and Nacogdoches. In 1817 the Anglo-Americans joined the Mexican revolutionists and with a force of only 800 men defeated the Spanish Army of 2,500 near San Antonio, a victory which led to Mexico's revolt from Spain in 1821. This part of Texas became a department of the State of Coahuila (co-a-wee′la) and Tejas (tay′has), of the Republic of Mexico. The name Tejas was derived from a confederation of friendly Indian tribes which occupied part of the eastern section of the State. Texas is the old Spanish spelling of Tejas, but the pronunciation has been anglicized. After Mexico won its independence many colonists from the United States were admitted under the leadership of "empresarios," of whom the most famous and most successful was Stephen F. Austin. Owing largely to this fact, Texas desired to be separated from Coahuila and recognized as a State of the Republic of Mexico. This was not acceded to, and instead Mexico in 1830 forbade further colonization by adjacent nations and in 1832 placed the coast region under military rule. All this caused so much discontent that in 1832 the uprising began which led to the declaration of independence from Mexico in 1835. An attempt at subjugation by Mexico led to the crushing defeat of the Mexican Army under Gen. Antonio López de Santa Ana at San Jacinto, near Houston, by the Texans under Gen. Sam Houston in 1836. From this time to 1845 Texas was an independent republic, with ministers to foreign courts as well as to Washington. Mexico repudiated the treaties made after the Battle of San Jacinto (ha-seen'toe) and made various raids with transient success. The proffer of annexation to the United States made by Texas after the Battle of San Jacinto was accepted only after nearly 10 years, when, in December, 1845, Texas was admitted as a slave State.

Texas as a division of Mexico did not extend beyond the Nueces River, but the Texas Congress in December, 1836, marked the limit as the Rio Grande. Mexico protested against this claim. After the Mexican War brought the Territory of New Mexico into the United States the compromise of 1850 removed from Texas the part of New Mexico that lies east of the Rio Grande and areas now included in the States of Oklahoma, Kansas, Colorado, and Wyoming. For this and other items relinquished Texas received a payment of $10,000,000.

The Sabine River has long been important as a boundary line, more or less contested. In 1806, by virtue of a semiofficial treaty between contending military authorities, it became the western boundary of a neutral territory extending from the Rio Hondo branch of the Red River (the present Calcasieu), and by the Florida Purchase in 1819 it was made the boundary between the United States and the Spanish possessions in the Southwest.

The traveler crossing Texas will be strongly impressed by the great change in vegetation that occurs every few hundred miles. This change is closely connected with climate, particularly the diminishing rainfall, and the increasing elevation to the west. Eastern Texas, with a mild, humid climate, has the Gulf flora, with longleaf pine (*Pinus palustris*),[28] the cane (*Arundinaria macrosperma*), bald cypress (*Taxodium distichum*), and many other characteristic species. About Orange, on the Sabine River on the Coastal Plain, only a few feet above sea level and with 50 inches of annual precipitation, there are many swamps with cane and reeds, cypress, and tupelo; bottom-land forests with magnolias, bays, pecans, hollies, oaks, gums, and

[28] Most of the botanic terminology in this section is taken from the Botany of Texas, by J. M. Coulter, Contr. U. S. Nat. Herbarium, vol. 2, 1891–1894.

thickets of palmetto (*Sabal glabra*). On the slightly higher slopes are heavy forests of longleaf and loblolly pines. At Houston, still on the Coastal Plain, the sand ridges are higher and many of them are forested with pine, but the western limit of this tree is soon reached. The prairies with wet-soil grasses have rushes, sedges, and many prairie annuals. Here the rainfall is about 45 inches. In the next hundred miles a rolling upland 300 to 400 feet high is traversed, with sandy ridges and rich alluvial bottoms. There is much grass land, abundant clumps of post oaks, scattered live oaks, and many sandy-soil species, besides several cacti of the "pricklypear" character, called "nopal" by the Mexicans. The rainfall is about 35 inches a year. About San Antonio, 316 miles west of the Sabine River, near the inner margin of the Coastal Plain, where the elevation has increased to 500 to 700 feet and the annual rainfall has decreased to 30 inches, the change in vegetation is very marked. Here the mesquite, huisache, cactus, zizyphus, yucca, and acacia, with many dry-soil grasses and annuals, are prevalent. On the Edwards Plateau, not far northwest, there is much small timber comprising numerous junipers, mountain live oak (encino), hackberry, shin oak, cedar elm (*Ulmus crassifolia*), and a few northern and Sonoran types, notably madroño (*Arbutus xalapensis*).

Near Spofford and Del Rio the western portion of the Rio Grande Plain is crossed. Its elevation is about 1,000 feet, and the annual rainfall averages 20 inches. Its surface consists of wide plateaus and low rolling ridges covered with gravel, sustaining much chaparral growth with plants more widely spaced than in the region to the east. The average height of woody growth also is much reduced. Mesquite predominates, but there are many other plants characteristic of semiarid regions. The creosote bush (*Covillea tridentata*) begins and from this region into California is a prominent member of the flora in many places. Cacti are more abundant, and the grasses are mostly in bunches. From a point near Langtry to and beyond Sanderson plateau topography prevails, with elevations of 1,300 to 2,000 feet, and the rainfall is about 15 inches. There is great development of sotol (*Dasylirion texanum*), lechuguilla (*Agave lechuguilla*), covillea, yucca, the allthorn (*Koeberlinia*), ephedra, many cacti, maguey, ocotillo (*Fouquieria splendens*), and bunch grass. This region has been called the sotol country. With gradually diminishing rainfall in the Marathon Basin the vegetation becomes more sparse and the cylindrical cacti appear, but in the mountains there are junipers, piñons, and other trees of similar habit. In the Davis Mountains small trees, mostly oaks, are also abundant, but in the descent to Marfa and in the wide basins beyond, the sandy soil has wide-spaced vegetation, the most conspicuous of which is the abundant yucca (*Yucca elata*). Toward El Paso, more than 900 miles west of the

Sabine River, with an annual rainfall of less than 10 inches, the desert conditions become still more pronounced, especially on the mesas, bolsons, and lower mountain slopes.

Although there is a great change in the character of the soil, from the deep moist earth of the east to the dry, open, unprotected soil of the west, the most important reason for the desert flora is the diminished supply of moisture. The average humidity of the air decreases from about 80 per cent in the eastern part of the State to less than 40 per cent in the far western part. There are, however, many complex factors in the adjustment of plants to zones in which moisture, sunlight, soil, and temperature are different.

Echo.
Elevation 16 feet.
Population 30.*
New Orleans 252 miles.

On the west side of the Sabine River is the old freight division station of Echo, about 6 miles north of Orange. Apparently this somewhat inconvenient location was necessary to obtain suitable conditions for a railroad bridge across the river. Along the east side of the river is a wide strip of marsh and on the west side pine-covered plains from 15 to 20 feet above sea level.

The wide area extending west from the Sabine River to San Antonio was for a long time a "no man's land," claimed in an indifferent fashion by both the French in Louisiana and the Spanish and Mexican authorities in the west. There was no legalized trade in this area, although the people of Louisiana trafficked with the Indian tribes. Outlaws and cattle and slave smugglers roamed at will, and lawless conditions prevailed even after the settlement of the boundary in 1819, just before the Mexicans revolted from Spain. This region was a complete wilderness in 1820 and 1821 when it was crossed with immense hardship by Moses Austin and later by his son Stephen F. Austin [29] when arranging to establish his colony of 300 families at San Felipe de Austin on the lower Brazos River.

Orange.
Elevation 18 feet.
Population 7,913.
New Orleans 258 miles.

Orange is on a wide plain on the west bank of the Sabine River. Until recently it had a lucrative lumber industry, with several sawmills cutting logs brought from the great long leaf pine region to the north.[30] Much of the product found a water outlet by way of the ship canal, 26 feet deep, which has been excavated down the Sabine River and Sabine Lake through Sabine Pass to the Gulf of Mexico. The projected Intracoastal Waterway will reach the Sabine River just below Orange and accommodate small vessels,

[29] The first notable map of Texas was prepared by Stephen F. Austin in 1829 and published in Philadelphia the following year. Reproductions of this map and an earlier one by Austin and also of a map of Mexican origin dated 1826 have been recently issued in Austin.

[30] There is also a large amount of other timber in the forests of southwestern Louisiana and southeastern Texas, including gums and oaks and some cypress. Much so-called mahogany is made from gum lumber.

which will carry freight east and west. At Orange is a paper mill using the sulphite process with yellow pine. In the region about Orange artesian water is obtained from sands in the Coastal Plain succession, and a well at the dock flows 200 gallons a minute. (Turn to sheet 5.)

In the lowlands west of Orange the southern margin of the great pine belt of southern Texas is crossed, and though there are many small farms of various crops, not much land is under cultivation. Cow Bayou, a tributary of the Sabine River, is crossed about 8 miles west of Orange.

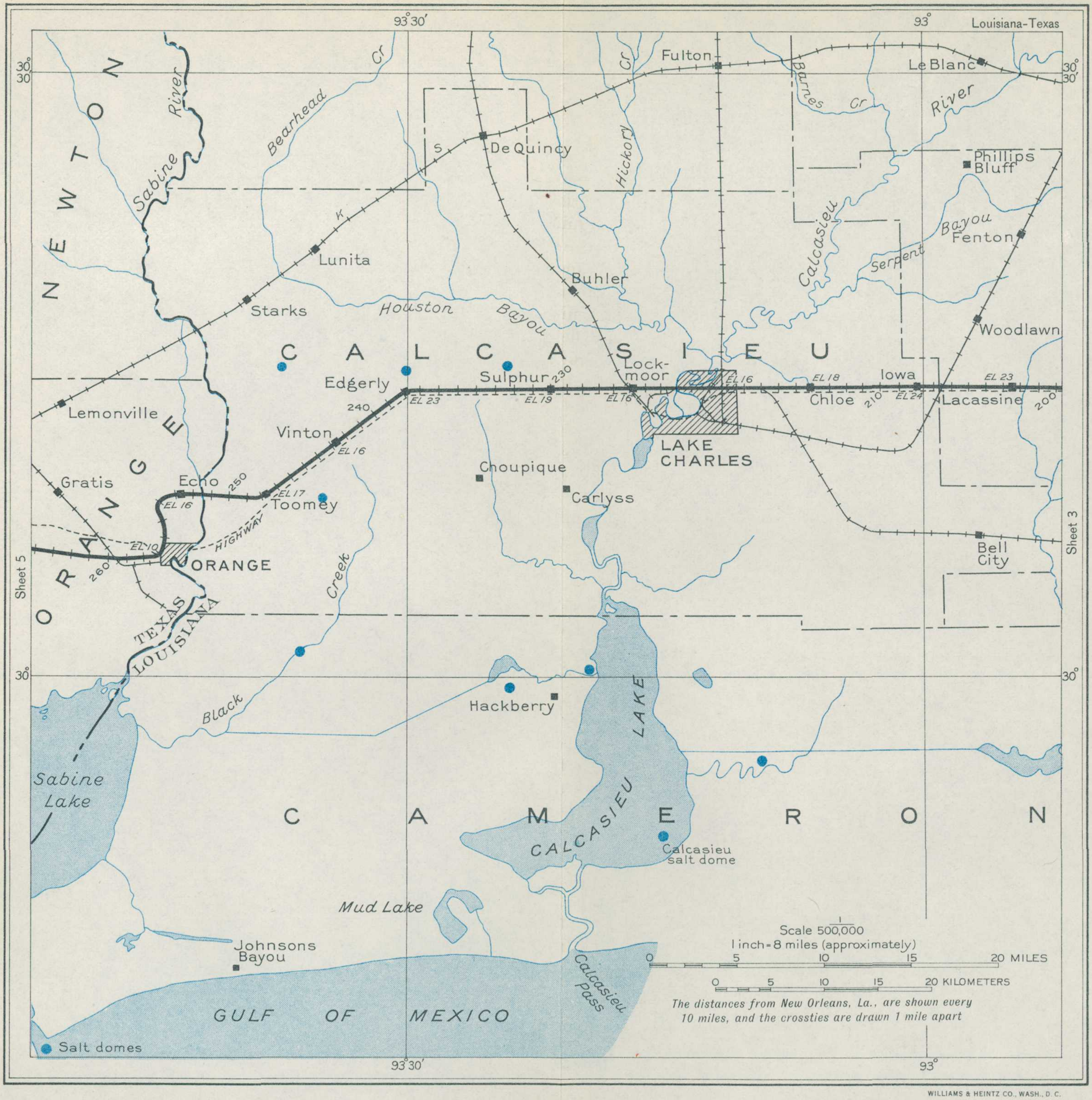
Small mounds are noticeable here and there west of Orange, most of them from 3 to 5 feet high and a few yards in diameter. They are "pimple mounds," similar to those mentioned on page 29. Six miles southwest of Orange is a group of derricks of the Orange oil field. This field, discovered in 1913, has had 416 borings, but at the end of 1930 only 86 wells were in operation, with a total yearly production of 790,000 barrels. The total production of the field to the end of 1930 was 27,716,594 barrels.[31] Some of the borings are 6,000 feet deep. No salt has been encountered. Another small field at Bessie Heights, some distance farther southwest, has a few deep wells and so far only a moderate supply of oil.

This is a region of wide level prairies with scattered clumps of pines and a few swamp areas of small extent. Just before reaching Beaumont the railroad crosses the Neches River (nay'chase), one of the moderately large streams of eastern Texas. Near Beaumont a swamp extends along its east side. In 1834 fair-sized steamboats were navigating the Neches, Trinity, and Brazos Rivers, with smaller boats using the lesser streams.

Beaumont.
Elevation 22 feet.
Population 57,732.
New Orleans 279 miles.

Beaumont is an important commercial center for eastern Texas, and its prosperity is indicated by the fact that its population increased 40 per cent in the decade from 1920 to 1930. From Beaumont to its mouth the Neches River has been dredged out as a ship canal (opened in 1917), 26 feet deep and 150 feet wide, capable of carrying vessels of as much as 15,000 tons dead weight, and it serves as an avenue for commerce, which in 1930 aggregated nearly 12,000,000 tons. The canal reaches Sabine Lake, 17 miles southeast of Beaumont, and, passing along the east shore of that water body, finds outlet through Sabine Pass into the Gulf of Mexico, a distance of about 35 miles. Sabine Lake and Sabine Pass are the drowned valleys of the Neches and Sabine Rivers, a condition doubtless resulting from subsidence in Recent geologic time. A large basin excavated at the

[31] These figures and some other totals for the other oil fields in Texas are taken from Texas Gulf Coast Oil Scouts Assoc. Bull. 1, 1930. The yearly figures are those published by the U. S. Bureau of Mines.



WILLIAMS & HEINTZ CO., WASH., D. C.

head of the ship canal serves as harbor and turning basin. According to the chamber of commerce at Beaumont, the value of exports from Beaumont through the canal was $75,000,000 in 1929, and more than 600 ocean-going ships, about half of them oil tankers, call annually. It is expected that the Intracoastal Waterway will soon be completed to connect with the ship canal at Port Arthur (population 50,902), 20 miles southeast of Beaumont. At Port Arthur is one of the largest oil refineries in the world, covering 4,100 acres, with several smaller ones and a large asphalt factory.

Originally Beaumont was developed by its large lumber industry, and even before oil was discovered near by it had a population in excess of 9,000. Its sawmills utilized the yellow pine from the forests to the north; these have been largely cut off, but will in time be in part reforested. At present there is a lull in the lumber business in this region, but there remain in the adjoining districts of western Louisiana and southeastern Texas large amounts of hardwood timber, comprising red and black gum, tupelo, and oaks of various kinds, that will eventually be utilized. Hardwoods are also imported cheaply from the Tropics. Many manufacturing plants have been established at Beaumont, notably the Magnolia Petroleum Co.'s plant and the Petroleum Iron Works. There are four rice mills and a large package rice plant, for Beaumont handles much of the rice of the adjoining country, which produces 2,000,000 bushels annually. Much cotton is exported, and sulphuric acid and paint are produced. Many railroads converge at Beaumont.

The great assemblage of oil tanks about Beaumont indicates that its principal interest at present is petroleum. It is stated that these tanks have a capacity of 70,000,000 barrels. There are in this vicinity 20 pipe lines bringing oil to great refineries that produce about 10 per cent of the oil products distilled in the United States. Their capacity is 266,000 barrels a day.

The famous Spindletop oil field is at Guffey station, 4 miles southeast of Beaumont, and the derricks are visible from the train. This field is a monument to the vision and persistence of F. A. Lucas, who discovered it and led the way to the discovery of many more fields of somewhat similar salt-dome structure, several of which have been described on previous pages. Gas and other indications of oil had been noted at Spindletop for a long time, and a small supply of gas was found in a well drilled in 1893. Early in 1901 Mr. Lucas "brought in" the gusher at a depth of 1,139 feet, of which the flow was 75,000 barrels or more a day, throwing a 6-inch stream of oil 200 feet in the air. In 1902 there were 1,200 wells with a production of 17,420,429 barrels. The yield declined to about 500,000 barrels in 1925; then,

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with the discovery of deeper sand, rose to nearly 21,000,000 barrels in 1927. The yield in 1930 was somewhat more than 6,000,000 barrels. The total production from 1901 to 1930 has been estimated at 115,163,000 barrels from an area of 265 acres. Some of the wells yielding the later production from the deeper sand are as much as 5,800 feet deep. The Spindletop mound is underlain by a salt core a mile in diameter with an anhydrite-gypsum cap, and the older sedimentary beds dip away steeply on all sides. The depth to the salt is 1,200 to 1,600 feet in greater part. (Fenneman; Barton and Paxton.) The relations are shown in Figure 3. The name is derived from a clump of timber near by which resembled an inverted spindle top.

West of Beaumont the railroad passes over a smooth plain which has a nearly regular rise from an elevation of 29 feet at Amelia siding to 77 feet on the east rim of the Trinity Valley west of Ames siding.

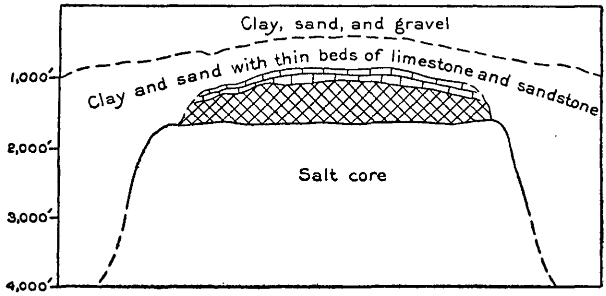


FIGURE 3.—Section through Spindletop salt dome, Texas. Partly after Fenneman

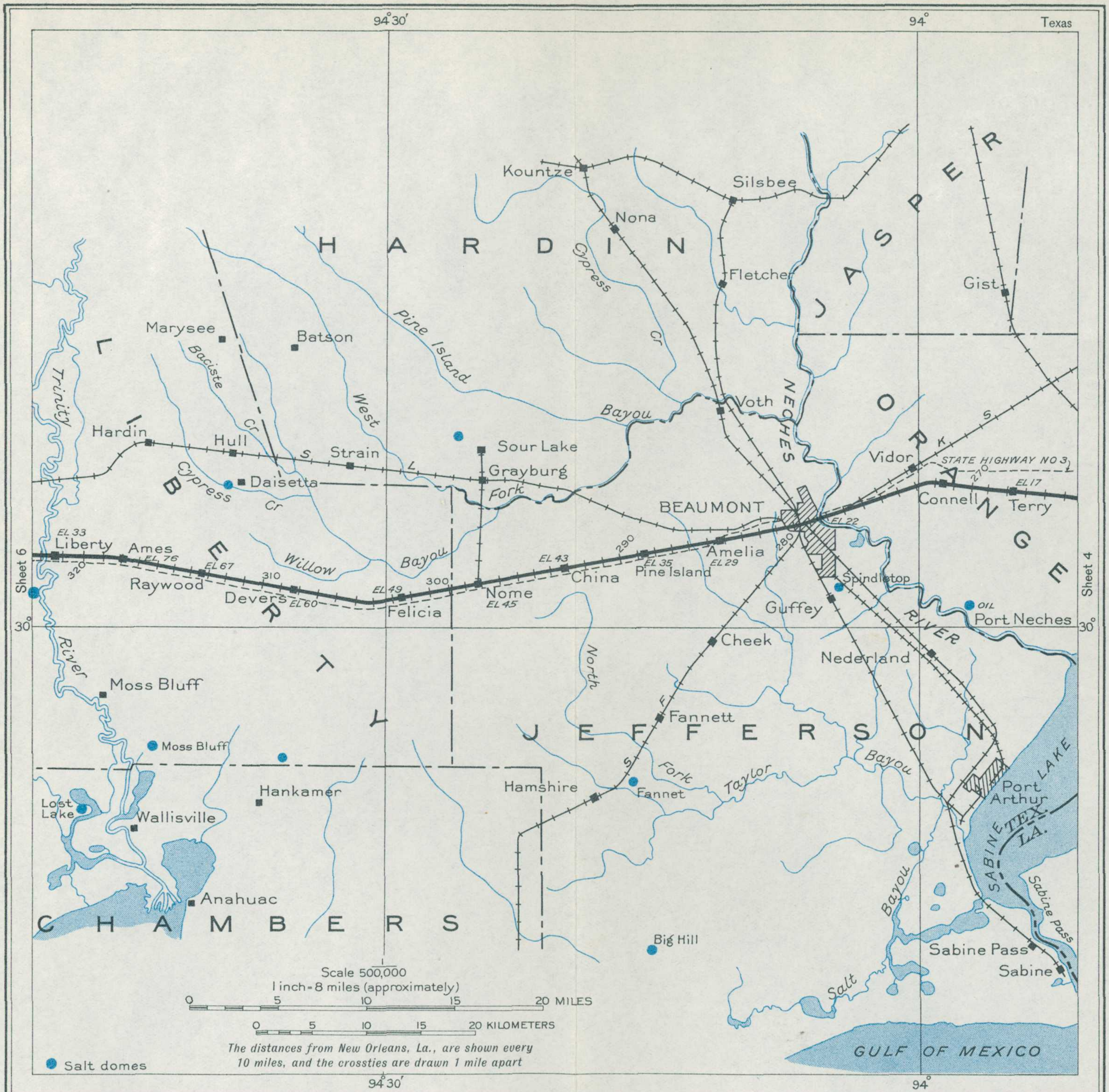
The geologic formation is clay and sandy clay (Beaumont), which is exposed at intervals in shallow road cuts and stream trenches. There are many wide prairies, with scattered woodlands, mostly of yellow pine and oak, and numerous plantations, some of them about Amelia devoted to fig raising. Rice fields occupy large areas, and ditches for water for their irrigation are crossed by the railroad at intervals.

Nome.
Elevation 45 feet.
Population 150.*
New Orleans 299 miles.

From China to Nome the configuration of the alluvial deposits marks a wide old stream bed believed to have been the channel of the Trinity River in Pleistocene time. (Barton.) From Nome to Raywood, a distance of 22 miles, there are many ridges composed of sand deposited by streams which formerly crossed the region.

Devers.
Elevation 60 feet.
Population 250.*
New Orleans 309 miles.

Seven miles south of Devers is the Hankamer oil field in a dome discovered in 1929 by torsion-balance exploration. It yielded 546,000 barrels in 1930 from 13 wells. At Devers the railroad crosses the pipe line of the Pure Oil Co., one of the many pipe lines which convey petroleum from the oil fields to the refineries at Port Arthur.


Texas
94°30′
94°
30°
Sheet 6
Sheet 4
HARDIN
JASPER
ORANGE
LIBERTY
JEFFERSON
CHAMBERS
Kountze
Silsbee
Nona
Fletcher
Gist
Marysee
Batson
Voth
Hardin
Hull
Strain
Sour Lake
Grayburg
Daisetta
Vidor
STATE HIGHWAY NO 3
Connell
Terry
BEAUMONT
Liberty
Ames
Raywood
Devers
Felicia
Nome
China
Pine Island
Amelia
Spindletop
Guffey
Port Neches
Cheek
Nederland
Moss Bluff
Fannett
Hamshire
Hankamer
Lost Lake
Wallisville
Anahuac
Port Arthur
Sabine Pass
Sabine
Big Hill
GULF OF MEXICO
SABINE LAKE
TEX.
LA.
Trinity River
Neches River
Pine Island Bayou
West Fork
Cypress Cr
Baciste Cr
Willow Bayou
North Fork Taylor Bayou
Salt Bayou
Sabine Pass
OIL
Scale 500,000
1 inch = 8 miles (approximately)
0 5 10 15 20 MILES
0 5 10 15 20 KILOMETERS
The distances from New Orleans, La., are shown every 10 miles, and the crossties are drawn 1 mile apart
Salt domes

Liberty.
Elevation 33 feet.
Population 2,187.
New Orleans 321 miles.

Liberty, founded in 1831, is in the wide valley of the Trinity River, one of the great rivers of Texas, which rises west of Fort Worth and flows into Galveston Bay 20 miles below Liberty. This valley extends nearly to Dayton, where there is a steep rise to the ordinary prairie level. The swamp occupying part of the valley shows some cypress and gum trees with Spanish moss.

Three miles below Liberty on the Trinity River is the South Liberty salt dome and oil field. The salt here comes within 500 feet of the surface and has a thick capping of gypsum and anhydrite, topped by a thin body of limestone. Its area is more than 2 square miles, and the volume of salt is very great, for it has been penetrated 2,100 feet. The field, discovered in 1905, was not productive at first, but several holes finally obtained satisfactory supplies of oil. The production in 1930 was 1,503,000 barrels, and the total yield is estimated at 12,651,800 barrels. Some of the deeper wells penetrated to the Oligocene(?) beds, which are believed to underlie the Coastal Plain at a depth of about 2,900 feet.

Near Liberty was the "Champ d'Asile," where 120 French colonists who had moved from an unsatisfactory settlement in Alabama established themselves on Spanish soil in 1818. They were soon ousted by the authorities and retired to Galveston. (Turn to sheet 6.)

Dayton.
Elevation 84 feet.
Population 1,207.
New Orleans 327 miles.

From Dayton the railroad goes nearly due southwest to Houston. That the Coastal Plain is gradually rising in elevation is shown by the increasing depth of the trenches cut by rivers and creeks. On the broad prairie uplands considerable pine timber remains, and there are numerous farms, mostly of small size. About 7 miles northwest of Dayton is the small North Dayton oil field, discovered in 1905 and yielding 406,000 barrels of petroleum in 1930 and 1,605,100 barrels in all. The field occupies an area of about 300 acres and has salt at depths below 300 feet. The derricks of this field are visible north of Stilson siding.

About 6 miles southwest of Dayton is the Esperton (or Sheeks) dome, discovered by a torsion-balance survey made late in 1928. This dome lies deep under the sands and clays of the Coastal Plain, and the oil was found at a depth of about 3,300 feet. Wells nearly 6,000 feet deep penetrated the Jackson (Eocene) beds. (Bowman.) One test hole 7,836 feet deep did not reach salt. According to the Texas Gulf Oil Scouts Association, the production in 1930 was 846,486 barrels from 27 wells.

About 2 miles west of Crosby the San Jacinto River is crossed, flowing in a wide, deep trench in the smooth Coastal Plain. About 10 miles below this crossing the river is joined by Buffalo Bayou, which has been deepened into the Houston Ship Canal. It was on a rounded ridge just south of the junction of these two streams that the Battle of San Jacinto, which gave Texas her independence from Mexico, was fought April 21, 1836. This battlefield has been laid out as a handsome park reached by a highway from Houston, 20 miles west. In this battle the Texas army of 783 men under Gen. Sam Houston routed the Mexican army of about 1,550 men under Gen. Antonio de Santa Ana six weeks after the fall of the Alamo (ah′la-mo) in San Antonio. Houston's men were inspired by the battle cry, "Remember the Alamo." There was one swift charge of 15 minutes in which the stampeding Mexicans lost 630 killed, 208 wounded, and 522 prisoners, while the Texans, raw farmers with poor equipment and only 50 horses, lost only 6 killed and 23 wounded. Santa Ana was captured the next day, and after an imprisonment of eight months was sent back to Mexico, where, from 1832 to his death in 1876, he continued to be alternately revolutionist, President of Mexico, and exile.

Crosby.
Elevation 49 feet.
Population 417.
New Orleans 341 miles.

From the west bank of the San Jacinto River near Sheldon siding the railroad follows a straight course southwestward over the level plain of Beaumont clay to Houston. In the interval there are several bayous or creeks which cut steep-sided trenches; pine woods are on all sides, and in places a few palmettos are growing. South of the railroad near Houston is a large creosoting plant for the treatment of ties and other timber for railroad use.

Houston, the largest city in Texas, is built on the wide, level plains adjoining Buffalo Bayou. Its population increased slightly more than 111 per cent from 1920 to 1930. It is named for Sam Houston, renowned soldier, governor, and Member of Congress, who was elected the first constitutional President of Texas after it achieved independence through his victory over the Mexicans a San Jacinto. Once the capital of the Republic, long an important railroad center, Houston has added greatly to its commerce by a ship channel opened in 1920 from Galveston Bay to a great basin excavated on the eastern edge of the city, which has berths for 50 ocean liners. This waterway cost $20,000,000. According to the Houston Chamber of Commerce, nearly 15,000,000 tons of freight was handled on this waterway in 1930, including nearly 2,000,000 bales of cotton and a large amount of rice and lumber. It is visited by vessels from all parts of the world. Houston claims to be the greatest spot-cotton market in the world and to rank second in cotton export. It exports grain from Iowa, Kansas,

Houston.
Elevation 47 feet.
Population 292,352.
New Orleans 363 miles.

and Nebraska and receives oil by pipe lines from all parts of the south-central United States.

The city has many fine avenues, handsome residences, large modern office buildings, and numerous shade trees, parks, and gardens. Rice Institute, with an endowment of $10,000,000 and assets of $14,000,000, is a great educational establishment. Railroad lines connect Houston with the city and port of Galveston (population 52,938), on the Gulf of Mexico, 50 miles to the southeast. (See pls. 5, *B*, and 6, *A*.) Houston experienced its first railroad activity as early as 1853 and was connected with neighboring towns long before 1881, when the first train arrived from New Orleans.

The first settlement at Houston was made early in 1836, when it was the head of navigation for small boats on Buffalo Bayou. It was the capital of the Republic until 1840, when a new capital was ordered established at Austin.

On the southern outskirts of Houston, at Pierce Junction, there is a salt dome that produces a large amount of petroleum. Originally the place was marked by a slight mound on which gas was found in shallow borings. Considerable drilling was required to develop the field, the first 54 holes being unsuccessful. From 1901 to 1930 a total of 19,637,240 barrels was produced from 86 wells, and the production in 1930, at about 10,000 barrels a day, amounted to 3,847,000 barrels. The oil comes in greater part from depths of 3,500 to 4,600 feet, from strata of lower Miocene, Oligocene(?), and Eocene age on the flanks of the uplift, where the beds are tilted up against the salt core. The top of the salt here is about 630 feet below the surface. One later hole 5,260 feet deep is a producer. From 1,300 feet to about 4,000 feet are pink and other colored clays interbedded with sand and gravel. Gray and blue clays below 4,000 feet are regarded as probably Oligocene. The basal Miocene appears to lie 3,500 to 3,600 feet below the surface near the dome and 3,800 to 3,900 feet below farther away from the uplift. (Bowman.)

From the Sabine River westward nearly to Columbus, eastern Texas presents a plain with wide areas of level lands and low terraces trenched slightly by valleys of the larger drainageways. The elevation of this plain, which is near 15 feet at the east, rises to 50 feet near Houston, to 100 feet beyond Richmond, and to 225 feet on the divide between the San Bernard and Colorado Rivers. To the north it extends to the Hockley scarp, at which there is a distinct rise. The lower part of the plain is mantled by a deposit of clay and silt known as the Beaumont clay, and the upper terraces to the north and west are covered by a sheet of sand and gravel known as the Lissie formation, both regarded as of Pleistocene age. The boundary between these two formations has not been mapped exactly, and only the general outline of their history is known. Underneath is the eastward-dipping succession of Coastal Plain formations, including a great thickness of strata of Tertiary age which have been penetrated by many deep borings. They are listed on page 50. Some of them yield artesian waters which supply flowing wells. The Lissie sand contains bones of animals of Pleistocene age, including the mastodon and mammoth, which have been found in gravel pits near Columbus.

It is interesting to picture the assemblage of animals which ranged over this country a short time ago, in a geologic sense, and which are now entirely extinct. Many of them were very different from the animals of to-day, but were similar to animals found on other continents. Notable among these were the large elephantlike mastodons and mammoths. The former (*Mammut americanus*), which was covered with long, coarse hair, ranged over a wide area, especially in the forested tracts. There were also mammoths of several species, notably *Elephas columbi*, which attained an average height of about 11 feet, and *Elephas imperator*, which was considerably larger. They had huge curved tusks and teeth like those of modern elephants, with large grinding surfaces; apparently they lived on the open plains. Horses of several kinds and sizes were abundant, apparently ranging in immense herds over the wide interior plains, but after having persisted from a very remote period geologically they became entirely extinct here long before the coming of the Europeans with the modern horse. Tapirs were abundant in the south-central areas, and camels, wild hogs, and llamas were widely distributed. Deer and bison (buffalo) were plentiful, and some species of these have continued into the present era. The carnivores were varied and numerous, including the saber-toothed tiger, and some of these may have been contemporaneous with primitive man. Among the more curious-looking animals were the ground sloths, large unwieldy creatures covered with long hair and moving slowly, walking on the outer edge of their feet. Their enormous claws may have served for defense, but were very useful in dragging down branches of trees and digging roots and tubers. The *Megalonyx*, one variety of the sloth, was discovered and named by Thomas Jefferson, who was greatly interested in natural history. Another genus was *Megatherium*, which had a body as large as that of an elephant and much shorter legs. The genus *Mylodon*, smaller and lighter than the other genera, was common in part of the plains region. Giant armadillos existed in some parts of the region, and there was a great variety of rodents, reptiles, birds, and other animals, which have been replaced in large part by different genera and species. The modern armadillo, which abounds in part of central Texas, is shown in Plate 9, *A*.

Three miles south of Missouri City is the Blue Ridge salt dome and oil field, with numerous derricks on and near two hills that rise a few feet above the general plain. There is also a shaft sunk for the salt that constitutes the core of the uplift below a depth of 450 feet and is at least 850 feet thick. It is estimated that 250,000,000 tons of salt is available. Development of the petroleum began in 1903, but there was little production prior to 1919, when several good strikes were made that gave a production of 326,000 barrels in 1921 and a peak production of 2,205,000 barrels in 1928. In 1930 the production was 644,000 barrels. In structure this mound is very similar to the one at Pierce Junction and other places—a stocklike core of salt with anhydrite cap, with the older strata considerably uplifted on its flanks. The dips on the east side are reported as 35° to 45°, and those on the west side seem to be greater. An oil sand at 3,900 feet is probably in the top of the Oligocene, and this apparently is the source of the oil in most of the successful wells. In one well the base of this division is placed at 3,410 feet, and a sample at 3,662 feet yielded fossils classed as "low in the Jackson" (upper Eocene). (Hager and Stiles.)

Missouri City.
Elevation 84 feet.
New Orleans 382 miles.

The smooth plain of the Houston region extends widely with its thick cover of clay and loam. Much land is under cultivation with large fields of cotton and other crops. Many figs are raised, an industry which is growing rapidly. A few scattered oaks are noticeable, and Spanish moss is present on trees in some of the ill-drained areas. A short distance west of Stafford, north of the tracks, is the radio broadcasting station KPRC.

Stafford.
Elevation 87 feet.
Population 89.
New Orleans 383 miles.

Sugar Land lies in the bottom lands of the Brazos River in the midst of a 17,500-acre plantation on which large amounts of cotton and garden truck are raised. Here the dark soil of the Lake Charles type gives place to chocolate-brown soils deposited by the overflow of the Brazos River. Sugar Land is a center of various industries. Its most conspicuous feature is a refinery which handles raw sugar imported through Galveston and has a capacity of 1,500,000 pounds a day. In this section artesian wells afford excellent water from the deposits that underlie the Coastal Plain.

Sugar Land.
Elevation 82 feet.
Population 2,019.
New Orleans 388 miles.

Four miles southwest of Sugar Land is the De Walt oil field, in a salt dome of small extent discovered by geophysical methods and proving to be rich and productive. It is controlled by one oil company and had a production of 4,274,000 barrels in 1930. The derricks are plainly visible from the train. The oil comes from sands overlying the salt, which is at a depth of about 4,300 feet.

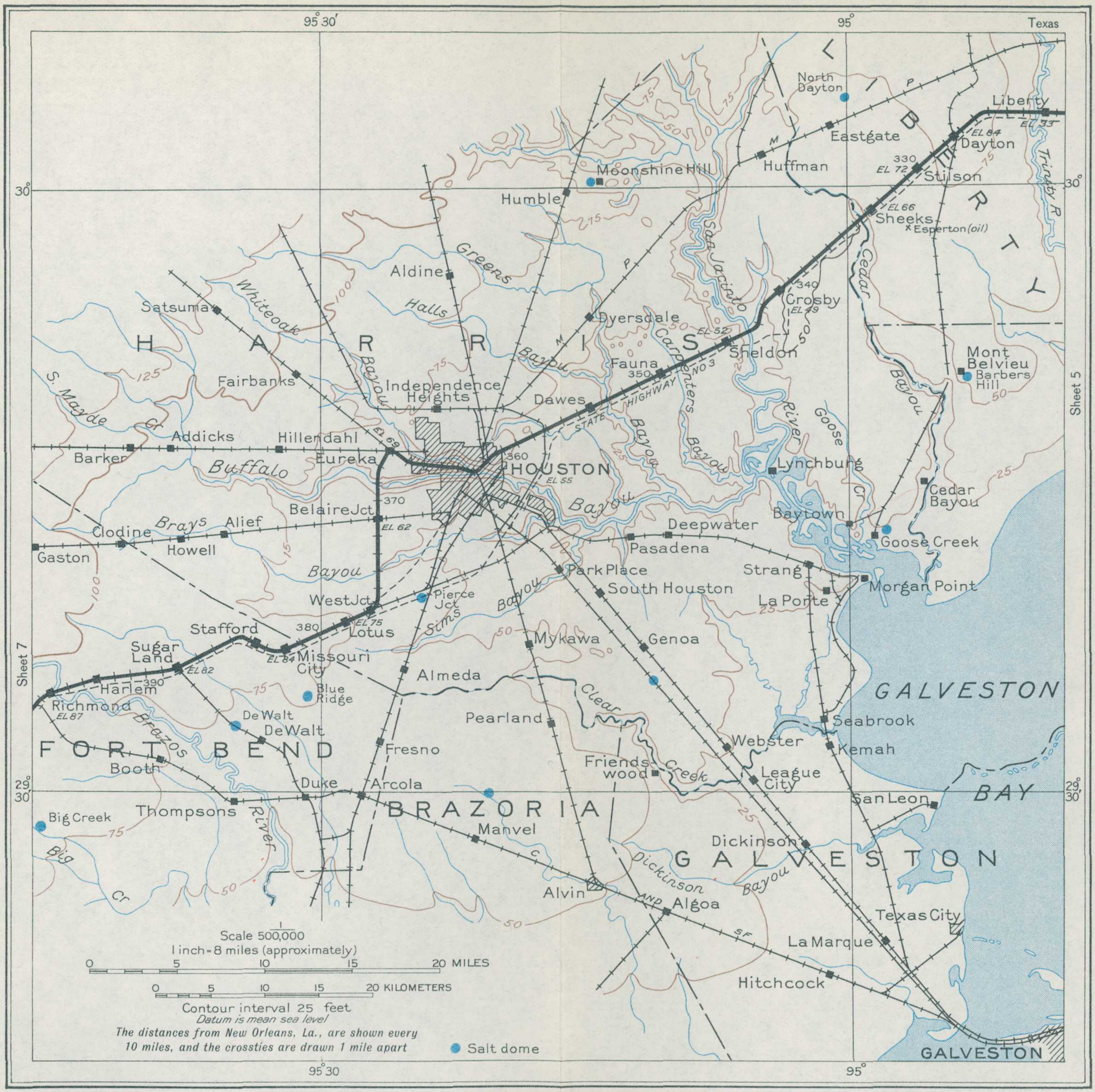
West of Sugar Land are the extensive cotton and corn fields of the State farm "Sartartia," and half a mile to the north is a canning factory in which the State preserves vegetables of many kinds for use in State institutions.

Richmond.
Elevation 87 feet.
Population 1,432.
New Orleans 387 miles.

On approaching Richmond the railroad crosses the Brazos River, one of the largest streams in eastern Texas. It is more than 900 miles long and drains a wide area in the central part of the State. Its headwaters are the Salt and Double Mountain Forks, which rise in the Llano Estacado. Its deposits are of pronounced reddish tint, owing to material derived from red beds far to the northwest, a feature which causes the marked change of soil that is observed just east of Sugar Land. The banks of this river are from 20 to 30 feet high at Richmond, revealing the sand and clay that underlie the adjoining plains. West of Richmond the river water is pumped to the top of the bank into a canal to supply water for irrigating rice fields lying to the southeast. In Richmond, where he died in 1837, is a statue erected by the State to the memory of Erastus (Deaf) Smith, one of the patriots active in the campaign that culminated in the Battle of San Jacinto.

From this place a railroad to Corpus Christi passes through Goliad, about 120 miles to the southwest, near which is the ancient presidio of La Bahia (bah-ee'ah), located here in 1749. At Goliad on March 27, 1836, three weeks after the fall of the Alamo, the entire garrison of 400, mainly Anglo-American volunteers, were slaughtered by order of the Mexican General Santa Ana.

Goliad, one of the oldest of the Spanish settlements in Texas and an important post throughout colonial and Revolutionary times, is now one of the shrines of the State. Here the first pronouncement of Texas independence was made by 91 citizens on December 20, 1835. The formal declaration by the convention on March 2, 1836, was made in the town of Washington, on the Brazos, some 50 miles north-northwest of Richmond. Halfway to Washington on the Brazos is San Felipe (fay-lee'pay) at the site of San Felipe de Austin, the colony organized by Stephen F. Austin in 1821, which was the predominant Anglo-American settlement until the revolution of 1836. Here in 1832 was held the first convention of the people of Texas, which established the committee of vigilance and safety that had charge of the earlier endeavors to preserve the constitutional rights of Texas as a department of a Mexican State. It was superseded as the capital by the younger city of Houston and later by the purposely founded city of Austin, on the Colorado River. (Turn to sheet 7.)


Texas
HARRIS
LIBERTY
FORT BEND
BRAZORIA
GALVESTON
GALVESTON BAY
HOUSTON
Liberty
Dayton
Eastgate
Huffman
North Dayton
Moonshine Hill
Humble
Stilson
Sheeks
Esperton (oil)
Crosby
Sheldon
Aldine
Dyersdale
Fauna
Dawes
Satsuma
Fairbanks
Independence Heights
Addicks
Hillendahl
Barker
Eureka
Belaire Jct
Clodine
Alief
Howell
Gaston
West Jct
Pierce Jct
Stafford
Lotus
Sugar Land
Missouri City
Harlem
Richmond
Blue Ridge
De Walt
Booth
Duke
Arcola
Fresno
Thompsons
Big Creek
Manvel
Alvin
Algoa
Almeda
Mykawa
Pearland
Friendswood
Park Place
South Houston
Genoa
Pasadena
Deepwater
Lynchburg
Baytown
Goose Creek
Cedar Bayou
Mont Belvieu
Barbers Hill
Strang
La Porte
Morgan Point
Seabrook
Kemah
Webster
League City
San Leon
Dickinson
Texas City
La Marque
Hitchcock
GALVESTON
Trinity R
San Jacinto River
Cedar Bayou
Goose Cr
Greens Bayou
Halls Bayou
Whiteoak Bayou
Carpenters Bayou
Buffalo Bayou
Brays Bayou
Sims Bayou
Clear Creek
Dickinson Bayou
Brazos River
Big Cr
S. Mayde Cr
STATE HIGHWAY NO 3
Sheet 5
Sheet 7
95° 30′
95°
30°
29° 30′
Scale 1/500,000
1 inch = 8 miles (approximately)
0 5 10 15 20 MILES
0 5 10 15 20 KILOMETERS
Contour interval 25 feet
Datum is mean sea level
The distances from New Orleans, La., are shown every 10 miles, and the crossties are drawn 1 mile apart
Salt dome
WILLIAMS & HEINTZ CO., WASH., D. C.

Rosenberg.
Elevation 106 feet.
Population 1,941.
New Orleans 400 miles.

Rosenberg is a commercial center for a large farming and dairy district and the junction of several branch railroads. Twenty miles south-southwest of Rosenberg is the Boling salt dome, a large uplift which has yielded some oil and contains an enormous body of sulphur.[32] The town of New Gulf (population 1,700*) has been established here, and the sulphur is being melted by steam and pumped up to the surface by the Frasch process. (See p. 32.) The deposit lies at depths of 450 to 1,200 feet and is believed to contain from 50,000,000 to 60,000,000 tons of sulphur. Two huge sulphur blocks have been made, each 600 feet long, 200 feet wide, and 40 feet high, as shown in Plate 6, *B*, and a still larger one is in progress. The material is about 99 per cent pure. The investment at this place is said to be $14,000,000. The production in 1930, according to the United States Bureau of Mines, was about 750,000 long tons, shipped largely to Galveston for water transportation.

Damon Mound, 20 miles south of Rosenberg, is a prominent feature in the flat lowlands, above which it rises 83 feet to an elevation of 140 feet. It is due to a typical salt dome in which a steep-sided plug of almost pure rock salt is capped by gypsum, anhydrite, and limestone. The salt mass penetrates and uplifts Tertiary formations, which dip away on all sides at steep angles. As in many other salt domes, the uplifted strata contained petroleum, most of it here being in sandstone and limestone of Oligocene(?) age. Up to 1924 the production was more than 5,000,000 barrels from 85 wells, and in 1930 the yield was 224,000 barrels. About the mound and penetrated by shallow wells are red, blue, brown, and yellow clays of the Beaumont formation, apparently deposited around the uplift. The salt core, which is of great but unknown thickness, comes within about 500 feet of the surface under the heavy cap rock, which is present in all domes. It is estimated to contain more than 1,000,000,000 tons of salt (Bevier). Damon Mound was an important headquarters for the Karankawan Indians, as shown by the presence of many fragments of pottery, burial grounds, stone implements, and arrowheads. The Indians regarded the "sour earth" of the mound as good medicine, and it had a favorable reputation over a wide area. This sour earth is due to the seepage of mineral solutions, which are usually present about a salt mound.

[32] About 58 miles to the south there is another large sulphur mine at Big Hill (Gulf), which has been producing since 1919, and other deposits occur at Hoskin Mound, Bryan Heights, and Longpoint. The Boling oil field produced 378,000 barrels a day in 1930, the amount having been gradually diminishing since 1926. The first sulphur mined in Texas was obtained at Bryan Mound in 1913; now Texas produces 97 per cent of the output of the United States and 85 per cent or more of the world's output.

The geology of eastern Texas is not very impressive to the observer traveling by train until the Colorado River is crossed and the regular succession of Tertiary and Cretaceous strata comes to the surface. Roemer, the pioneer geologist of Texas, writing in 1846, when San Antonio was the frontier, said, "It is only where civilization ceases and the wilderness commences that the geological relations of the country begin to be interesting." Of the region around Columbus, Gonzales and Seguin, he remarked, "You see no solid rock in place excepting irregular layers of a coarse calcareous sandstone * * * exposed on the steep banks of some of the river; * * * the surface is covered with loose materials." However, later studies have brought to light in this region the following very interesting succession:

Formations of east-central Texas exposed near the Southern Pacific lines

[Most of the information regarding the Tertiary formations has been supplied by Julia Gardner]

Age	Group	Formation		Principal materials
Quaternary.		Alluvium and terrace deposits.		Gravel, sand, and loam. Nonmarine.
Pleistocene and Pliocene(?).		Lissie and Reynosa formations.		Gravel, sand, and clay. Nonmarine.
Pliocene.		Lagarto clay.		Massive green, gray, and brown clays stained purple and red toward the top, with abundant calcareous nodules and a few thin sandstones. Nonmarine.
Miocene.		Oakville sandstone.		Massive, in part cross-bedded yellowish or grayish indurated sandstones and brown calcareous clays. Nonmarine.
		Catahoula sandstone.		Light-colored sands and loosely indurated sandstones and clays, many of them ashy. Mostly nonmarine.
Eocene.	Jackson.	Fayette sandstone.		Thin-bedded light-gray pepper and salt sandstone with interstratified leaf-bearing clays and thin beds of volcanic ash. Mostly nonmarine.
	Claiborne.	Yegua ("Cockfield") formation.		Dark-brownish, gray, and greenish-gray clays and clayey sands, many of them carbonaceous. Mostly nonmarine.
		Cook Mountain formation.		Glauconitic fossiliferous sands and sandstones, marls, and clays. The basal member (Sparta sand) a loose or loosely indurated nonmarine sand.
		Mount Selman formation.	Weches greensand member.	Glauconitic and oolitic sandstones indurated with an iron cement; glauconitic clays; marine and sparsely fossiliferous.
			Queen City sand.	Rather fine light-gray or iron-stained sands with thin interstratified light-gray clays. Nonmarine.
			Reklaw member.	Glauconitic fossiliferous sands and clays, in large part stained and indurated with iron oxide.
		Carrizo sand.		Very coarse and pure quartz sand, loose or packed with little or no cementing material. Nonmarine.
	Wilcox.	Indio formation.		Bedded yellowish-brown and red sands and sandstones and dark-colored clays, for the most part nonmarine. A few concretionary beds, the concretions carrying a few marine fossils.
		Midway formation.		Dark-gray clay with concretions and sandy clays; rarely a thin fossiliferous ferruginous sandstone near the top.

The formations below the Lissie occur in widely extended sheets which dip at a low angle to the southeast. As the rate of dip is greater than the rise of the land, their outcropping edges come to the surface in regular succession to the west. This relation is shown in the cross section on sheet 8. They are conformable in attitude, but some of them are separated by unconformities.

Near Tavener a group of derricks off to the north marks the Orchard oil field, which has had a small production from a salt dome that was discovered by geophysical tests on the surface.

Just east of East Bernard the San Bernard River [33] is crossed in a valley about 30 feet deep, containing cypress, oak, and other trees of the lowland flora. Not far beyond the bridge the railroad deflects to the northwest across a broad plain that extends beyond Eagle Lake and is in large part occupied by rice fields.

East Bernard.
Elevation 125 feet.
New Orleans 416 miles.

Eagle Lake is a shallow body of water lying in a depression due to an old bend of the former course of the Colorado River. It contains considerable water, especially after rains, and is used as a reservoir for water pumped from the river and then into a canal for irrigating rice fields to the east. On the east slope of the depression, a mile or more south of Eagle Lake town, are banks 10 to 20 feet high showing gravelly cross-bedded compact sand, regarded as Lissie. There are also cuts in this material near the railroad just west of the town.

Eagle Lake.
Elevation 174 feet.
Population 2,343.
New Orleans 432 miles.

At Eagle Lake the railroad deflects to a course nearly northwest and, passing over a low ridge at Ramsey siding (elevation 222 feet), descends into the broad terraced valley of the Colorado River. The formation covering this region in a widespread mantle is the Lissie gravel; distinctive outcrops are rare, and few are visible from the train. Three miles southwest of Eagle Lake is an artesian well 1,506 feet deep, which has an excellent flow of tepid sulphur water. Four miles northwest of Eagle Lake the Lissie gravel is exposed lying on clay and sand with gravel (mostly chert) which may represent a separate formation. In the banks of the Colorado River 5 miles southwest of Ramsey siding and again on the slope 4 miles northwest of that place the formation known as the Lagarto clay is revealed. It consists of sandstone, in part conglomeratic, with interbedded clay, and is part of the great eastward-dipping succession of formations of Tertiary and Cretaceous age which come to the surface in regular order as given in the table on page 50 and as shown in section on sheet 8.

[33] The banks on the east side of this valley expose gray sandy clays, regarded (by Deussen) as the basal member of the Beaumont clay, which are underlain by Lissie sand and gravel (not exposed here). At the top is reddish sandy clay, probably alluvium.

In the region west of Eagle Lake much of the land is prairie with scattered clumps of timber, especially along the streams. Post oaks (*Quercus stellata*) are the most abundant trees and some of them reach a diameter of 2 feet and a height of 30 feet. Small hickories and live oaks (*Quercus virginiana*) are fairly common, and the yaupon or scrubby southern holly (*Ilex vomitoria*), hawthorn, buckthorn, and other small trees are widespread. Spanish moss festoons many of the trees in the lower lands, where also there are a few palmettos. Large "sycamores," or buttonwoods (*Platanus occidentalis*), live oaks, white oaks, pecans, black walnuts, cedars, and soapberry trees are widely scattered. A few shortleaf pines occur, notably in a small clump 3½ miles north of Alleyton. In the vicinity of Alleyton and Columbus cottonwood trees (*Populus fremonti*) appear along the larger watercourses, a feature which is characteristic in central and western Texas. There are also many willows in the lowlands, but cypress disappears. Yuccas begin, but they are not abundant.

Alleyton.
Elevation 189 feet.
Population 40.*
New Orleans 445 miles.

Near Alleyton there are deep gravel pits from which a large amount of material has been excavated for railroad ballast and road metal from an alluvial deposit of a terrace built by the Colorado River at a time geologically not very remote. The gravel pits are marked by great mounds of refuse stripping.

About 3 miles west of Alleyton the Colorado River is crossed; Columbus lies on its west bank. Near by at Beason's ford the Texans under General Houston camped for a while prior to their victorious battle at San Jacinto. The Colorado River rises in the central part of the State and empties into Matagorda Bay with a total length of about 715 miles. The name Colorado (Spanish, red) is appropriate, for when the river is in freshet the red beds which are traversed by its upper waters give it a large amount of red mud. About 75 miles above Columbus on this stream is Austin, the capital of Texas, founded in 1839 on 7,735 acres of land bought for this purpose by the Republic at a cost of $21,000.

Columbus.
Elevation 201 feet.
Population 2,054.
New Orleans 448 miles.

Columbus is a local business center for diversified farming interests, rice here giving place to a variety of crops and more extensive cattle raising and dairying. On the edge of the town is a flowing well of excellent water in small volume said to come from a depth of 1,400 feet. In the west bank of the river half a mile below the railroad bridge are conspicuous ledges of moderately compact gray sandstone overlain by softer gray sandstone, all of the Lagarto formation,[34]

[34] The Lagarto formation is largely a calcareous clay with a few soft, thin, irregularly bedded light-colored sandstones loosely held together by a calcareous cement. The clays are unstratified, plastic, and usually jointed, and their cleavage surfaces are stained with manganese oxide. They are commonly mottled in pastel tints of green, gray, and brown and near the top, where

capped by a sheet of alluvium which constitutes the terrace on which Columbus is built. This terrace extends west a short distance and abuts against or gives place to an upland of eastward-dipping reddish beds that contain much gravel and are regarded as the Lissie formation. These beds are well exposed in the railroad cut through the divide 2 miles west of Glidden. The Lagarto-Lissie contact makes a strong reentrant down the Colorado River Valley, and the railroad skirts this contact to a point about 4 miles west of Glidden before finally entering the Lagarto, which it crosses at an angle of about 120° to the strike. (See fig. 4.) From Glidden a branch railroad extends to Lagrange, on the Colorado River.

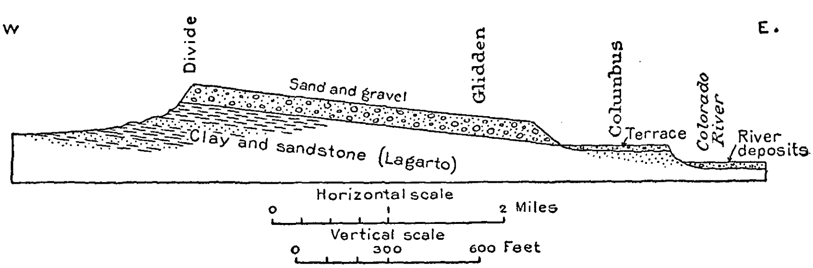


FIGURE 4.—Section along the Southern Pacific Railroad through Columbus and Glidden, Tex.

The clays and soft sandstone of the Lagarto formation extend west to and beyond Schulenburg. The outcrop zone of the Lagarto strata is mostly a rolling, treeless prairie of black calcareous clay, very heavy when wet, or, in the area of outcrop of the less argillaceous beds, a sandy loamy soil. Near the eastern contact post oaks and live oaks indicate that the higher elevations are capped with Lissie gravel. (Turn to sheet 8.)

In the vicinity of Weimar, about 2 miles east of the Fayette County line, the railroad attains the summit of one of the higher ridges in Colorado County constituting the divide between the Colorado and Navidad Rivers. Southeastern Fayette County, however, has been eroded by the two forks of the Navidad to an area of low relief.

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they are possibly stained by the iron oxide leached from the Lissie, in pastel purples and reds. Calcareous nodules are abundant in places. Limy conglomerate and limestone near the top may represent the overlying Reynosa formation. A few vertebrate remains, mostly of horses, and chara stems, together with reworked Cretaceous fossils, locally abundant, have been found in the Lagarto beds and in the deep wells near the Gulf a marine microfauna indicating a shore line slightly inland from the present coast. The formation is about 1,200 feet thick, and it dips to the southeast about 50 feet to the mile.

Through Weimar and Schulenburg and halfway to Engle siding the rolling surface of the Lagarto clay is traversed, but about Weimar there is an extensive flat or terrace. Good outcrops are rare, especially near the railroad, but there are shallow cuts in the western part of Weimar and there are exposures at intervals along the streams, especially in some of the bends of the Colorado River. A large part of the area is covered by soil and part is woodland. Remains of the 3-toed horse, *Protohippus perditus*, and other bones were found in the Lagarto formation at Dripping Springs, 1½ miles northeast of Borden siding. Shells derived from underlying Cretaceous formations and minute Foraminifera have been noted.

Weimar.
Elevation 410 feet.
Population 1,256.
New Orleans 463 miles.

At Shatto siding the railroad crosses the east branch of the Navidad River, which heads in the low ridges north of Schulenburg but develops into a drainageway of considerable size in the region farther south.

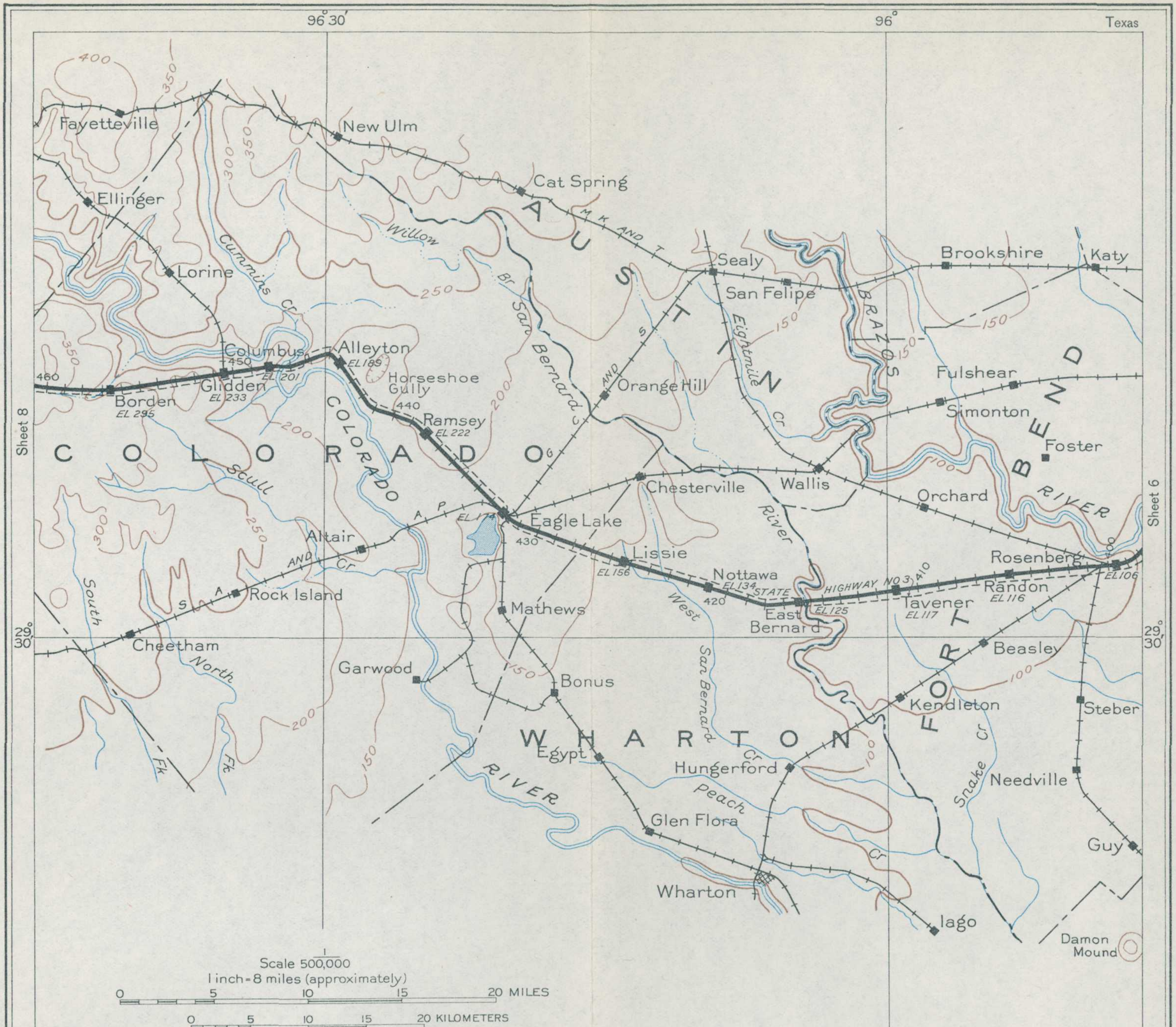
Schulenburg is a rural center for a prosperous agricultural district. Dairying is a thriving industry, and some of its products are utilized at a large plant making evaporated milk, on the western edge of the town. Near by is a mill which produces a nonstarchy flour from cottonseed. Just west of Schulenburg are cuts in light-colored sandstone, and near by are ledges of this rock. These beds dip east and are in the lower part of the Lagarto clay. The general dip of the strata in this region is considerably less than 1°, which is nearly 90 feet to the mile.

Schulenburg.
Elevation 345 feet.
Population 1,604.
New Orleans 471 miles.

Two miles west of Schulenburg the west branch of the Navidad River is crossed, and thence there is a long gentle upgrade that extends nearly to Flatonia. In this interval the Oakville and Catahoula sandstones appear, rising on a dip which is low in angle but steeper than the rise of the land. Both of these sandstones present low ridges and knobs, so that the country has a diversified topography, and as the soil is not very fertile much of the land remains wooded.

The contact between the Lagarto clay and the Oakville sandstone [35] is passed just beyond the west branch of the Navidad, whence the railroad follows the low divide between Rock Creek and Mulberry Creek.

[35] The Oakville sandstone is characteristically a massive light-gray or yellow rock, in part cross-bedded, in all about 300 feet thick and dipping to the southeast at the rate of about 40 feet to the mile. It is held together loosely by a calcareous cement, commonly crystalline, or, more rarely, it is firmly indurated. The sand grains are, as a rule, fairly coarse and subangular. Light-colored greenish or yellowish limy clays make up an appreciable part of the upper Oakville section, closely resembling in appearance some of the Lagarto clays. For this reason, the Oakville-Lagarto contact is less obvious than might be expected from the characteristic materials of the two formations. However, volcanic ash, both in its original



Topography mostly from U.S.Army maps

WILLIAMS & HEINTZ CO. WASH., D. C.

The landscape of the Oakville outcrop zone along the Southern Pacific Railroad is more subdued than it is from Lagrange northward or to the south. There are several excellent outcrops of this sandstone along the road leading north from Engle to Lagrange. Wild flowers, such as the bluebonnets (Texas State flower) and the mallows, which are the glory of the spring in Texas, are particularly luxuriant upon the sands derived from the Oakville ledges. The Catahoula-Oakville contact is about 3 miles east of Flatonia but is not visible in the lowland of the badly drained area at the headwaters of Mulberry Creek.

Flatonia.
Elevation 457 feet.
Population 966.
New Orleans 484 miles.

Two miles west of Engle siding a summit is attained, beyond which is a long, rolling slope to Flatonia, a thriving town in a community part German and part Bohemian, situated on the outcrop of the lower beds of the Catahoula sandstone.[36] Flatonia was named from J. Flato, who kept a store at the original site of the town, 2 miles south of the present one. It has an interesting position

form and altered to bentonite, is apparently restricted to the Oakville sandstone, and the dendrites (plant-like forms due to a deposit of manganese oxide) that so commonly occur on the cleavage planes of the Lagarto clays have not been observed in the Oakville clays. Reworked Cretaceous fossils occur as pebbles in both formations. The Oakville contains few marine fossils in place but many remains of vertebrates have been found in it, including primitive horses of several kinds, rhinoceroses, crocodiles, and tortoises, and it is classed as late, middle, and early upper Miocene in age. It is underlain unconformably by the Catahoula sandstone, although the rate of dip of both formations is about the same.

[36] The Catahoula consists of soft bluish massive sandstone and interbedded clays, but the sand grains, unlike those of the Oakville, are dominantly rounded and poorly sorted and probably in part of dune origin. The formation is about 200 feet thick and lies conformably on the Fayette sandstone. Near Flatonia the sands are loosely cemented by a calcareous matrix, but elsewhere a blue opalescent quartzite matrix is not uncommon. The clays are greenish gray or yellow, are mostly sandy, and carry limy clay balls an inch or more in diameter similar to those now forming at the salt-water mouths of some large streams. The sands are relatively less abundant in Fayette County than they are to the north, toward the Sabine River, where on the outcrop area there are long stretches of pine woods. Opalized wood and clear impressions of tropical palms are locally abundant. According to E. W. Berry (U. S. Geological Survey Prof. Paper 98, p. 229, 1917), this flora contains no upland or inland types and may be regarded as a strictly coastal assemblage made up of groups comparable with those found along the strand in the present-day Tropics. To the south the formation contains deposits of volcanic materials ejected from vents located possibly in southern McMullen and Duval Counties. Volcanic activity during the Catahoula deposition was not, however, restricted to southwest Texas, for most of the larger fuller's-earth deposits of this region, notably that near Corrigan, in Polk County, are in the Catahoula. The Catahoula outcrop zone in Fayette County is largely overgrown with post oak, and the relief is relatively low compared with that of the Oakville sandstone. The clays weather to a black soil and are very heavy when wet.

topographically, for it is on the notably flat divide between the Colorado River, which heads far west in the outcrop area of the Permian "Red Beds," and the Guadalupe River, which heads on the Edwards Plateau. The town site is just beyond the heads of the fingering tributaries of the intermediate coastal streams, such as the Navidad River. Obar Hill, less than a mile south of Flatonia and rising more than 100 feet above the village, is capped by heavy beds of white sandstone, probably an Oakville inlier. The well at Flatonia, 3,000 feet deep, is supposed to obtain its excellent water supply from the Carrizo sand.

The Fayette-Catahoula contact is about 1 mile west of the crossing of the old San Antonio & Aransas Pass Railway (now Texas & New Orleans) in Flatonia, where the fine-bedded sands of the upper Fayette lie below the greenish-gray compact clays of the basal Catahoula.[37] The varied lithology of the Fayette sandstone is expressed in the diversity of the landscape and the vegetation. The soil is more highly colored, as a rule, than that of the Catahoula, and the contrast between the black clay roads and post oak of the lower Catahoula and the red sandy roads and junipers of the upper Fayette is very striking. The configuration of the Fayette outcrop is noticeably different from that of the outcrop of the underlying Yegua formation, though it is not so rugged as that of the Catahoula and Oakville sandstones.

A little more than a mile beyond Janice siding the railroad passes from the dominantly sandy Fayette strata to the Yegua beds, which are gray, green, and brown lignitic clays and sandy clays with thin sand deposits. They are highly gypsiferous and, for the most part, nonmarine. They are about 500 feet thick, and all the beds dip to the east at a low rate. The outcrop zone is a region of low hills with gentle slopes. Generally the soil is dark and loamy with scattered mesquite (*Prosopis juliflora*) and prickly pear (mostly *Opuntia engelmanni*); more rarely it is a fine sandy loam with a few post oaks. The mesquites growing on Yegua soil in this region are larger than those in the region to the south, probably because of a greater supply of moisture. However, this plant withstands dry weather by sending its taproot as deep as 50 feet to obtain moisture. The mesquite, which begins to be conspicuous in this general region, is a dominant

[37] There are fine exposures of the formations in road and stream cuts both north of the railroad, toward Muldoon, and to the south, especially in the vicinity of Nickel, where 75 feet or more of kaolinitic shales and concretionary sands and sandstones at the top of the Fayette are overlain by the sandy clays filled with clay balls that characterize the basal Catahoula. The Fayette formation consists of light-gray thin-bedded sands, dark-gray and chocolate-brown clays and lignites, and, in its upper part, thin beds of volcanic ash. The thickness is about 65 feet. The basal Fayette in this general section commonly carries cylindrical concretions of iron oxide an inch or so in diameter oriented at a high angle to the bedding planes.

plant in many parts of the region to the west across Texas, New Mexico, Arizona, and southern California. Its beans are an important source of food for grazing animals and they are used for flour by the Indians and Mexicans. The wood is a most useful fuel, and the plant yields a valuable gum; a decoction of the bark is esteemed by the Mexicans as a laxative.

The high percentage of gypsum in the Yegua strata makes the soil unfavorable for many crops and the water unsuitable for stock, so that the outcrop area of the formation is rather thinly settled. About 2½ miles east of Waelder the railroad deflects to the north and follows the divide between Sandy and Copperas Creeks, crossing the rather ill-defined contact between Yegua and Cook Mountain strata about 1 mile east of Waelder.

Waelder.
Elevation 378 feet.
Population 1,048.
New Orleans 495 miles.

Sandstone of the Cook Mountain formation makes a ridge of moderate prominence that extends far to the north and south of the railroad. The formation includes sands and glauconitic marls and clays,[38] some of them lignitic but for the most part of marine origin. The higher beds are locally fossiliferous, and many of the species were early correlated with those of the sands of the Claiborne of Alabama. The glauconitic beds of the Cook Mountain formation are highly colored by the oxidation of the iron, and in many places the formation carries an appreciable content of phosphate, which serves as a fertilizer. The Cook Mountain greensand soil is highly productive, and cotton, corn, and garden truck are successfully grown along its outcrop. The basal member of the Cook Mountain is the Sparta sand, probably nonmarine, carrying less iron than the higher beds. Its outcrop zone, from 1 to 2 miles wide, is crossed by the railroad on the down grade to the valley of Bee Branch, 4 miles west of Waelder. The vegetation varies with the formation; the mesquite here is not so large nor so numerous as in the Yegua area, but the oaks are very much more in evidence, especially on the lower, more sandy beds.

On leaving the outcrop zone of the Sparta sand member of the Cook Mountain formation the railroad bends considerably to the south, and for the next 5 miles, or nearly to Harwood, it crosses the Mount Selman outcrop diagonally. The strata dip to the west-northwest at a low angle. In a general way the Mount Selman beds resemble the Cook Mountain formation, consisting of glauconitic sands, marls, and clays, but they contain a greater number of indurated, irony beds, so that the hills and ridges are higher and the soil a more intense red. The soil is productive and well adapted to truck farming, and a large part of the 25,000 acres planted in tomatoes in

[38] The mineral glauconite, also called greensand, is a silicate of iron and alumina deposited in the sea through organic and chemical agencies.

Texas in 1930 was upon an outcrop of the upper member of the Mount Selman. The medial sand member, known as the Queen City sand in northeastern Texas, contains clay deposits, some of which carry fossil leaves, and the series is, for the most part, nonmarine. This sand member is uniform in character, and in the Winter Garden region in southern Texas it is sufficiently thick and pure to carry water of a quantity and quality second only to that in the Carrizo sand. Post oak and blackjack oak are the characteristic trees growing on the heavier sands, but where a little clay is mixed with the sand the forest growth is varied, and in well-watered areas the underbrush is heavy.

The lowest member of the Mount Selman formation along the Southern Pacific Railroad has been separated as the Reklaw. It consists of ferruginous sands and brownish and grayish glauconitic micaceous clays of marine origin, possibly less than 100 feet thick. The railroad crosses the outcrop zone, about 1 mile wide, at the small village of Harwood. The soil and landscape sharply reflect the lithology of this member, the clay outcrop forming a low flat belt and a heavy soil which in wet weather makes very difficult roads, whereas the ferruginous, concretionary beds at the base give much more relief and better-drained though much rougher roads. The hilly character of this region is due to the capping of these resistant basal beds of the Reklaw upon the soft, readily eroded Carrizo sand. Both the basal ferruginous layers and the clays above carry fossils. The ferruginous beds contain impressions of *Venericardia* and *Corbula*, which in places are fairly common; the glauconitic clays carry locally, notably on the Colorado River near Bastrop, a well-preserved and varied coral and molluscan fauna.

Harwood.
Elevation 461 feet.
Population 225.
New Orleans 508 miles.

On the western edge of Harwood the shale at the base of the Mount Selman formation gives place abruptly to the Carrizo sand, one of the most characteristic of the Texas Tertiary formations. The airplane maps show this formation as a solid pale-gray ribbon picoted along the margins by the darker pattern of the Reklaw above and the Indio beneath. The sand is coarse and almost pure white, and consists of nearly pure quartz grains, loosely packed and readily weathered, blowing about the fields and resisting cultivation. The bright-colored indurated layers occurring at intervals in the sand and the local capping of the Reklaw ferruginous strata along the eastern edge of the outcrop break down into rugged, castellated shapes, contrasting sharply in color and relief with the soft, dazzling white sand. Rather scrubby oaks are the most conspicuous trees, and the few and difficult roads wind through long uninhabited stretches broken only here and there by a lumber or goat camp. In certain Carrizo areas where the sand is coarser and less pure it is adapted to the growth of some kinds of garden truck. The Carrizo sand is the underground reservoir that furnishes the water to irrigate many fields and gardens, notably in the Winter Garden area of western Dimmit and Zavala Counties and in the extensive trucking district south of San Antonio, particularly the strawberry farms near Poteet, in northern Atascosa County. In the Winter Garden area, where the annual rainfall is less than 25 inches and the native vegetation was mostly mesquite and nopal, irrigation by water from the Carrizo sand has made a garden spot that abundantly justifies the name.

Along the Southern Pacific Railroad the Carrizo outcrop is a rather monotonous belt of sand and scrubby oak extending from a point just west of Harwood to and beyond Ivy siding. Iron Mountain, one of the higher hills, consisting largely of hard brown sandstone, causes a deflection of the railroad to the north for some distance east of Ivy siding, beyond which it passes onto the outcrop zone of the Indio formation. There are fine exposures of the basal sandstone of the Carrizo in the cut through the divide a mile west of Ivy, which reveals about 30 feet of coarse, mostly soft massive sandstone containing considerable ironstone and notably cross-bedded.

These beds are underlain by a thick body of softer sandstones and clays of the Indio formation. This constitutes the surface of a wide area about Luling, where, however, the strata are mostly covered by alluvium, especially in the flat that extends west to the San Marcos River.

Luling.
Elevation 411 feet.
Population 5,970.
New Orleans 517 miles.

The outcrop of the Indio formation is wider along the Southern Pacific Railroad than that of any other of the Tertiary formations, largely because the railroad crosses it diagonally in the northerly bend near Luling and also in the southward deflection of the tracks west of that place. Most of this outcrop zone is gently rolling and rather featureless, though it presents the threefold division of a lower and an upper clay and shale series, locally of marine origin and fossiliferous, separated by nonmarine sands and sandy shales. The soils of the Indio formation vary with the lithology. Some of them are almost as sandy, though not so coarse, as the Carrizo sand; others are almost as heavy and black as the Midway soils; but most of them respond to cultivation. Blackjack oak and post oak are the common trees on the more sandy soils, and mesquite predominates on the clay soils.

The large "tank farm" of the Magnolia Petroleum Co., a mile east of Luling, indicates the proximity of the Luling oil fields. Before the discovery of petroleum here in August, 1922, Luling was a small, easy-going German community, concerned chiefly with the price of cotton, on which the material welfare of the inhabitants depended. The discovery of oil at a horizon lower than that of any other source then producing in the Texas fields not only changed over night the resources and status of the community and of its individual members, but opened new possibilities of finding deep productive sands throughout the State. The Luling field was discovered by Edgar B. Davis, a shoe manufacturer of Brockton, Mass., who drilled to the Edwards limestone, against the counsel of other oil operators, at a cost of $200,000. The large fortune which he gained from his success was shared with the rapidly growing community; streets were paved, clubs and orphan homes were developed, and the Foundation farm of 1,200 acres was established near by with a trust fund of $1,000,000 for experimental farming for the benefit of the people of the region.

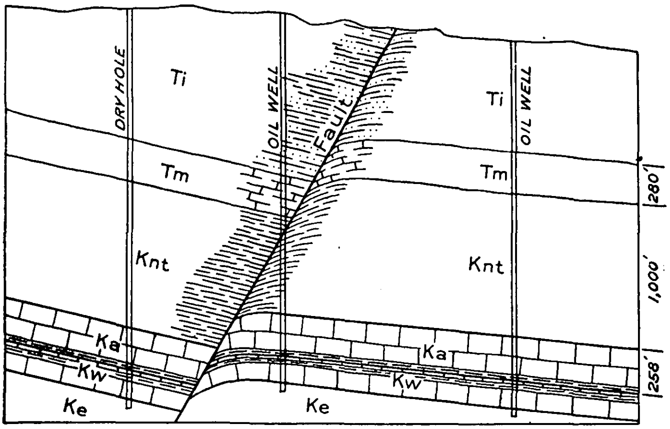


FIGURE 5.—Section across Salt Flat oil field, Caldwell County, Tex. Tertiary: Ti, Indio formation; Tm, Midway formation. Cretaceous: Knt, Navarro and Taylor clays; Ka, Austin chalk; Kw, Georgetown limestone overlain by Del Rio clay and Buda limestone; Ke, Edwards limestone

There are three productive oil fields near Luling—the Salt Flat field, to the northeast of the town; the Darst Creek field, to the southwest; and the Luling field, to the northwest. There are also some smaller pools. All have the same geologic relations.

The many derricks of the Salt Flat oil field are conspicuous north of the tracks a few miles east of Luling. In 1930 this field produced from 15,000 to 27,200 barrels a day, with a total of 7,305,000 barrels for the year, from about 330 borings. Their average depth is 2,700 feet, and most of the oil comes from the Edwards limestone, which has been lifted by a fault with upthrow of about 375 feet. The field was discovered in 1928 and up to the end of 1930 had produced 21,116,554 barrels of oil.[39] The field is about 2,000 feet wide at most and 6 miles long, extending along the main fault, which trends northeast. The surface beds are sands and shale of the Indio formation,

[39] Southwest Texas Oil Scouts Assoc., Bull. 1, 1930.

which is 700 feet thick in this vicinity.[40] The relations are shown in Figure 5.

A few miles southwest of Luling is the Darst Creek oil field, discovered in 1929 and also drawing from the Edwards limestone, the depth of which in the first well was 2,605 feet. The oil here, as in the other fields near by, is believed to have migrated up the dip and become trapped in the upper porous member of the Edwards limestone, here sealed off by a fault that has brought it up against impervious strata. This fault is estimated to have a displacement of about 525 feet. It trends northeast, parallel to the Luling and other faults. (Brucks.) The production in 1930 ranged from about 15,000 to 36,452 barrels a day and amounted to 11,424,000 barrels for the year from about 253 wells. The productive area is about 4½ miles long and in places 3,500 feet wide, covering about 1,500 acres.

In the Luling field, which is nearly 8 miles long and half a mile wide, the oil occurs in the upper part of the Edwards limestone, at an average depth of about 2,100 feet. This field reached a peak production of about 11,134,000 barrels in 1924, with 567 wells, but in 1928 it had diminished to half that amount, and in 1930 it yielded 3,692,000 barrels, or about 10,000 barrels a day. The total production to the end of 1930 was about 50,000,000 barrels. The oil has a gravity of 26° to 29° Baumé.[41]

Some interesting data have been obtained from borings in the Luling field as to underground temperatures. In general the temper-

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[40] Below the Indio are 280 feet or more of tough clays and glauconitic sands of the Midway group (basal Tertiary), which lie unconformably on Navarro clay, here about 500 feet thick and containing some thin beds of sandstone. Next below are about 500 feet of Taylor clays and chalky clays, which extend to the Austin chalk, 228 feet thick, underlain by the Eagle Ford shale, 30 feet; Buda limestone, 60 feet; Del Rio clay, 40 feet; and Georgetown limestone, 60 to 110 feet, lying on the Edwards limestone. (McCullum and Cunningham.) See also table, p. 65.

[41] According to Brucks the structure, which is similar to that in the Salt Flat and Darst Creek fields, shows a faulted monoclinal block with northeast trend. The upthrow is about 450 feet on the southeast side, and at the surface the basal clays of the Indio formation are brought up into contact with a medial sandy member. The fault is well exposed where it crosses the San Marcos River about 6 miles northwest of Luling.

In this field the Eagle Ford shale is 35 feet thick; the Buda limestone, 40 feet; and the Georgetown, a compact limestone, 50 feet. The normal dip of the strata in this region is only 1°–2° SE. Deep test borings seeking oil-bearing beds at lower horizons show that the Edwards limestone, of which the upper part is porous, is about 730 feet thick. It is underlain by 1,450 feet of Glen Rose limestones and clays (Brucks) and Trinity sands, the Trinity lying on pre-Cambrian schist at a depth of about 4,790 feet. (See table, p. 65.) Into this schist drilling was continued nearly to 8,000 feet without the slightest prospect of reaching its base or of finding petroleum.

ature in mines and borings is found to increase with depth at an average rate of about 1° for every 60 feet, below the first few feet. In two 2,250-foot holes near Luling the temperature was found to be 120°, which indicates a rate of increase of 1° in slightly less than 45 feet. At Pierce Junction, near Houston, the temperature in a 3,300-foot hole was 130° and in a 4,303-foot hole 146°.[42]

The San Marcos River, which is crossed 3 miles west of Luling, has its principal source in the great springs at San Marcos, 30 miles northwest, at the foot of the Edwards Plateau. (Turn to sheet 9.)

Kingsbury.
Elevation 605 feet.
Population 200.*
New Orleans 528 miles.

West of the San Marcos River the railroad passes over a wide lowland of the Indio formation to a point beyond Sullivan siding, where it ascends about 100 feet onto a high terrace. This terrace is underlain by the Indio formation but covered and preserved by a compact deposit of gravel and sand carrying much chert evidently derived from the Edwards Plateau. This deposit extends north of the railroad for some distance as a cap on the Mill Creek Hills and undoubtedly was originally deposited by an earlier San Marcos River in late Tertiary time.[43] In the descent off this terrace west of Kingsbury there are exposures of the Indio formation, mostly soft sandstone and a few hard layers. Beyond this down grade is a wide lowland extending to Seguin (say-gheen').

Seguin.
Elevation 551 feet.
Population 5,225.
New Orleans 538 miles.

Seguin is on the alluvial plain of the Guadalupe River, here underlain by lower shaly beds of the Indio formation. It is a prosperous town, with cotton mill, sugar refinery, and various other industries. Water power is generated from the Guadalupe River a short distance north of the town. Seguin was founded while Texas was a republic and was named from two Spanish settlers who lived in the vicinity during the stirring days of the Texas revolution. One was Don Erasmo Seguín, of San Antonio de Bexar (bay'har), who had a share in creating the constitution of Texas, and the other Juan Seguín, who commanded a small body of Mexicans who fought effectively under General Houston in the battle of San Jacinto.

A gravel pit about 2 miles west of Seguin, south of the railroad, shows about 10 feet of gravel grading up into sand, the upper part of

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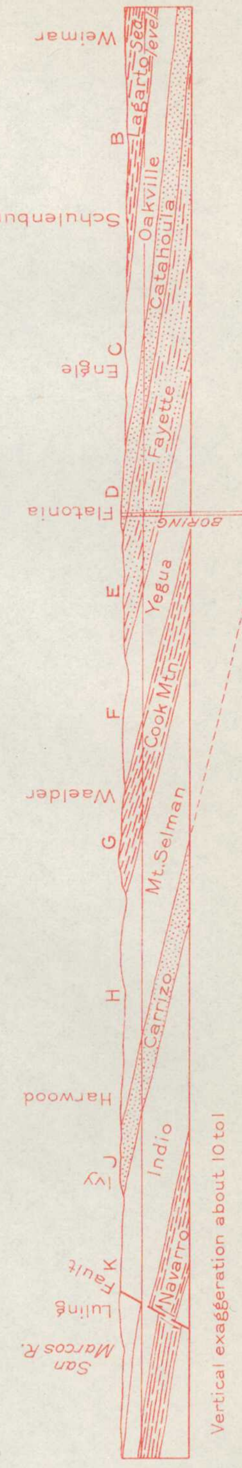
[42] Hawtof, E. M., Am. Petroleum Inst. Bull. 205, pp. 62–108, 1930.

[43] Most of the interstream divides on the higher portion of the Coastal Plain are capped by gravel deposits of this character. They are remnants of an old surface, called the Uvalde plain because it is very extensive in the Uvalde region. This plain has been largely removed by streams, which in general have cut valleys 200 feet or more deep, many of them along courses differing materially from the drainage ways that crossed the old Uvalde surface. Notable remnants of this plain remain about San Antonio and south and east of New Braunfels, San Marcos, and Austin.



SECTION FROM WEIMAR THROUGH LULING

Vertical exaggeration about 10 to 1

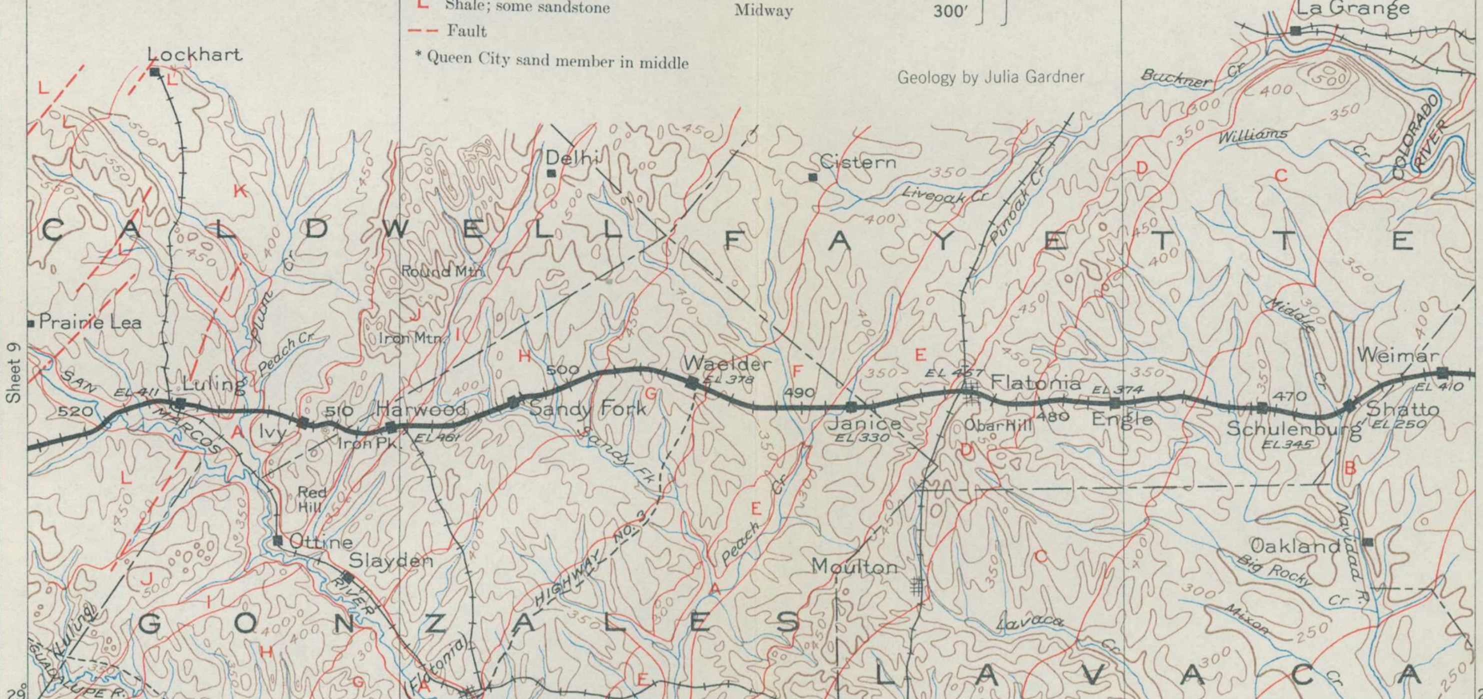
EXPLANATION

A	Sand, gravel, and loam (alluvium) (only the larger areas shown)		0–50′	QUATERNARY
	Unconformity			
	(Older terrace deposits, Reynosa, etc., not shown)			
	Unconformity			
B	Clay, pink and green mottled	Lagarto	400–600′	TERTIARY, *Pliocene*
	Unconformity			
C	Sandstone	Oakville	300–600′	TERTIARY, *Pliocene*
	Unconformity			
D	Sandstones (underlain by Frio clay to south)	Catahoula	300′+	TERTIARY, *Miocene*
	Unconformity			
E	Sandstone	Fayette	500–800′	TERTIARY, *Eocene*
F	Clay with few sandy beds	Yegua	400–500′	TERTIARY, *Eocene*
G	Sandstones and clays, much glauconite and iron oxide	Cook Mountain (including Sparta sand member at base)	400–700′	TERTIARY, *Eocene*
H	Sandstone and shale (iron ore)	Mount Selman*	400–600′	TERTIARY, *Eocene*
I	Irony sands and dark clay		80′	TERTIARY, *Eocene*
	Unconformity			
J	Sand and sandstones	Carrizo	250′	TERTIARY, *Eocene*
K	Sandstone, shale, and sandy limestone	Indio	1,200′	TERTIARY, *Eocene*
L	Shale; some sandstone	Midway	300′	TERTIARY, *Eocene*

– – Fault

* Queen City sand member in middle

Geology by Julia Gardner



Scale 500,000

1 inch = 8 miles (approximately)

0 5 10 15 20 MILES

0 5 10 15 20 KILOMETERS

Contour interval 50 feet

Datum is mean sea level

The distances from New Orleans, La., are shown every 10 miles, and the crossties are drawn 1 mile apart

Each quadrangle shown on the map with a name in parentheses in the lower left corner is mapped in detail on the U. S. G. S. topographic map of that name

Topography from U. S. Geological Survey quadrangle maps; east of longitude 97° by Engineer Corps, U. S. Army

WILLIAMS & HEINTZ CO., WASH., D. C.

which consists of caliche. This material occurs in most parts of the West and is frequently mistaken for stratified limestone. Much of it is hard and white or nearly white, and it consists largely of calcium carbonate with a greater or less admixture of sand. It owes its origin to water rising through the porous materials by capillary attraction and depositing calcium carbonate on evaporation at and near the surface. Doubtless the rate of accumulation is very slow, and ordinarily the caliche or at least the thicker bodies of it are found only on old plains or terraces in regions of low precipitation. The thickness ranges from a few inches to 10 feet or more. The pit west of Seguin gives a fine exhibit of this material and its relations to the gravel and sand.

Just west of Seguin the Midway group,[44] or base of the Tertiary system, is brought to the surface from under the Indio formation by the regular rise of the strata to the west. It consists of shale with thin layers of sandstone and clay and is sufficiently hard to constitute ridges in places along its outcrop zone. Such ridges attain considerable prominence in the Mill Creek Hills, west of Seguin, which, however, are gravel-capped, and in the hills that extend southwestward to San Antonio.

The contact between the Indio and Midway formations on the northwestern margin of Seguin and that between the Midway formation and the Cretaceous strata, 3 to 4 miles to the west, are covered by alluvium in the lowlands along the Guadalupe River. There is, however, a good outcrop of a fossiliferous and ferruginous sandstone of a horizon high in the Midway near the old ferry 2½ miles above the Seguin power house.

The Guadalupe River, which is crossed just east of Hilda station (McQueeney village), is a large and beautiful stream that drains a broad area of the Edwards Plateau (p. 74) and south-central Texas and

[44] The Midway consists, for the most part, of dark-gray joint clays with associated cannon-ball, turtle-back, or cone-in-cone concretions and locally carries a microfauna. No large fossils have been recorded from the upper Midway clays of this area. The thickness is between 250 and 300 feet. In Guadalupe County the lower Midway strata crop out characteristically only along a slender faulted tongue southwest of Staples, on the San Marcos River. Most of the Midway surface material is a very heavy dark-gray clay which weathers into a soil indistinguishable from the river silts, and the usual vegetation is stunted mesquite. Guadalupe and Bexar Counties must have formed a synclinal basin during the early Eocene, for marine conditions apparently persisted, at least intermittently, well into Indio time. The waters were for the most part shallow, for *Ostrea* and *Cerithium* are the most common species at the lower Indio outcrops. Even these, however, record the continuance of the general marine conditions of Midway time and indicate that there was a near-by retreat for the very considerable number of Midway species that persisted into Wilcox time.

empties into the Gulf of Mexico at the head of San Antonio Bay. Although there is a wide alluvial plain adjoining the river, formations of Upper Cretaceous age are extensively exposed at intervals in its banks and adjoining slopes. The uppermost of these is the Navarro, which consists almost entirely of dark clay from 400 to 500 feet thick, with some beds of sand and layers of calcareous concretionary sandstone and impure limestone. In this general region the Navarro formation dips somewhat less than 1° E. The clay is quarried extensively in pits near the river bank about a mile south of the bridge across the Guadalupe River at the village of McQueeney and is made into brick and tile used in San Antonio and other places. Ordinarily in the manufacture of such products a pure clay, which melts at a moderate temperature, has to be tempered by mixing with sand, but at this place there is sufficient sand or sand admixture to afford suitable composition to withstand the requisite heating in the kilns. The exposure comprises a bank about 100 feet high and a pit 50 feet deep. Fossils [45] are abundant in the lower part of the pit.

Marion.
Elevation 644 feet.
Population 540.*
New Orleans 548 miles.

From the Guadalupe River to San Antonio the railroad traverses a region of slightly rolling plains of low relief developed in the soft clays of the Navarro and Taylor formations, here about 1,300 feet thick and dipping gently to the southeast. Outcrops are few and small, for soil and superficial materials cover most of the surface, and much of the land is under cultivation. The mesquite is very prominent in the untilled fields. Southeast of Schertz a large gravel pit in the alluvial deposits on the Cibolo River is visible from the railroad. To the west is a hilly country of Austin chalk, and beyond is the highland known as the Balcones scarp (bal-co′nace), formed of the hard limestones of the Lower Cretaceous (Comanche series), which there rise to the surface on the general southeast dip of all the strata of the Coastal Plain region, the uplift increased in places by faulting. The Upper Cretaceous strata (Gulf series) crop out in a wide zone along the inner margin of the Coastal Plain, which extends through Fort Worth, Dallas, Waco, Austin, and San Antonio. They are underlain by the formations of the Comanche series, which constitute the high uplands to the west and north. The table on page 65 shows the general succession and principal features.

[45] A few of the better-known fossils that occur in the Navarro formation in this area are *Leda longifrons*, *Gryphaea mutabilis*, *Exogyra costata* (variety with narrow costae), *Gryphaeostrea vomer*, *Pecten argillensis*, *Lima acutilineata*, *Pulvinites argentea*, *Crenella serica*, *Liopistha protexta*, *Veniella conradi*, *Cyprimeria alta*, *Legumen ellipticum*, *Gyrodes petrosus*, and *Sphenodiscus* (two or more species). (L. W. Stephenson.)

Cretaceous formations of the Coastal Plain in central Texas

Age	Group	Formation	Character	Thickness (feet)
Upper Cretaceous (Gulf series).		Navarro	Shale and marl; some sandy layers	400-500
		Taylor	Shale	475+
		Austin	Chalk and chalky limestone	300
		Eagle Ford	Shale and slabby limestone	25
Unconformity —				
Lower Cretaceous (Comanche series).	Washita.	Buda	Limestone, massive	60
		Del Rio	Clay, buff	50-70
		Georgetown	Limestone, massive	75±
	Fredericksburg.	Edwards	Limestone, massive; some chert	400-500
		Comanche Peak	Limestone, slabby	50±
		Walnut	Clay and shaly limestone	50-70
	Trinity.	Glen Rose	Limestone and shale	700+
		Travis Peak	Sandstone.	

The Cibolo River (Spanish, buffalo), a small stream crossed at Schertz, drains a portion of the Edwards Plateau west of San Antonio. On the plain to the west, south of the railroad, is the great aviation establishment of the United States Army, known as Randolph Field. It was completed in 1931, with an area of 2,320 acres. Its capacity is 4,000 men. The high tower of its central administration building is conspicuous from afar, as are also the great hangars with checkerboard roofs. This establishment cost $25,000,000; the site was presented to the Federal Government by the city of San Antonio. The smooth, broad plain at this place has been developed on the soft clay of the Taylor formation.

Cibolo.
Elevation 704 feet.
Population 262.
New Orleans 554 miles.

Schertz.
Elevation 715 feet.
Population 315.
New Orleans 557 miles.

Not far beyond the small village of Converse some of the high buildings of San Antonio are visible in the distance, and beyond Kirby siding part of Fort Sam Houston is in sight on a high terrace north of the railroad.

San Antonio is a metropolitan center for a wide area in south-central Texas and until a few years ago was the largest city in the State. Its growth in population from 1920 to 1930 was 43.5 per cent. It has numerous manufactures, large educational institutions, and a variety of business interests. It is an old settlement dating back to Spanish mission days and, as San Antonio de Bexar, was long the capital of Tejas in New Spain under Spanish and Mexican rule, with a history marked by many sanguinary episodes.

San Antonio.
Elevation 675 feet.
Population 231,542.
New Orleans 573 miles.

It is a city of much charm, combining the old with the new in a setting of natural beauty. The San Antonio River [46] winds through the city with many curves and is crossed by bridges that afford pleasing glimpses of its greenswarded banks, even in the heart of the business district. There are many large edifices of architectural merit, and a fine municipal auditorium that seats 6,500 and cost $1,500,000. The mild winter climate is an attractive feature. Excellent water for domestic use and for many manufacturing establishments is supplied by artesian wells 900 to 1,200 feet deep from strata in the Coastal Plain sediments. According to the local chamber of commerce, the output of its 1,175 factories had a value of $85,000,000 in 1930. They have the advantage of cheap natural gas, oil, and lignite for fuel. San Antonio has many churches and clubs, several libraries and theaters, and many educational institutions. A women's college, Our Lady of the Lake, on the western edge of the city, is visible from the railroad a few minutes after leaving the depot.

On the outskirts of the city to the north is Fort Sam Houston, an Army post of 4,378 men and 211 officers, and to the south are extensive Army flying fields and schools. In Brackenridge Park, in the valley of the San Antonio River, are numerous features of interest, including a large zoological collection.

Although San Antonio has a large proportion of sunshiny days, its precipitation averages about 27 inches a year, or about the same as in much of the west-central United States. This is usually sufficient to produce fair crops and excellent forage, but there is considerable irrigation from ditches and from artesian and pumped wells. From 45 years of observation by the United States Weather Bureau it has been found that the mean annual temperature is 69°, the winters averaging about 60° and the summers 80°, and the average humidity is 68 per cent. The springs and autumns are long, but the summer heat at most times is tempered by breezes and low humidity.

San Antonio probably owes its origin to two great springs, with a total average volume of about 58,000,000 gallons a day,[47] that supply the flow in the San Antonio and San Pedro Rivers. It is believed that the water is derived from the Edwards limestone along a fault.

Probably the first Spanish visitor was Cabeza de Vaca, who crossed central Texas about 1535. In 1718 a garrison was stationed here, and

[46] This river, the outlet for the drainage of an extensive hilly area northwest of the city, sometimes has freshets which on some occasions have done considerable damage. To prevent these floods the great Olmos Dam has been built across the valley. Occasionally there are cloudbursts in this region and other parts of the West in which a large amount of rain falls in a very short time. There is a record of a succession of these at Taylor, Tex., on Sept. 9–10, 1921, in which 23.11 inches of rain fell.

[47] See Meinzer, O. E., Large springs in the United States: U. S. Geol. Survey Water-Supply Paper 557, pp. 37–38, 1927.

a mission was moved from the Rio Grande and renamed San Antonio de Valero in honor of the Viceroy of New Spain. In 1730 a presidio was erected here, and early in 1731 a colony of 16 Spanish families from the Canary Islands sent out by the King of Spain came through Mexico and established themselves with a few local people at the springs of the San Antonio River under the name San Fernando. This was finally merged into the presidio of San Antonio de Bexar and for many years called simply Bexar. Three years later this settlement was made the seat of government for the general region. In 1821 it passed into the possession of Mexico when she became an independent nation. In 1835–36, in the revolt against Mexico, San Antonio was a center of strife, culminating in the siege of the Alamo in February of that year. Many of the old-time buildings remain, including the Alamo, the 200-year-old palace of the Spanish governor on the west side of Military Plaza (pl. 7, *B*), San Fernando Cathedral, and several old missions. There is a large Mexican population, part of it in an extensive Mexican quarter south and west of the old plaza.

San Antonio was an important station on the old Camino Real from Monclova, Mexico, which crossed the Rio Grande below Eagle Pass. The mission San Francisco de la Espada, just south of the town, was built on this road. From San Antonio it led north and east to the vicinity of Natchitoches and thence to New Orleans.

The most notable feature in San Antonio is the famous Alamo (pl. 7, *A*), where 182 heroes, nearly all of them volunteers from different parts of the United States, chose to die rather than to surrender to twenty times their number of Mexican soldiers under General Santa Ana. At that time San Antonio was on the southeastern bank of the San Antonio River and consisted of well-fortified houses in a rectangle; on the opposite bank was the walled inclosure of the Alamo. The assaults lasted from February 23 to March 6, 1836, when the Mexicans overwhelmed the defenders, all of whom were killed. Now the Alamo is a museum exhibiting many relics of the glorious past of Texas and bearing this stirring inscription: "Thermopylae had its messenger of defeat—the Alamo had none." It was the war cry "Remember the Alamo" that spurred the Texans to victory at San Jacinto a few weeks later. (See p. 44.) Tablets near by mark the sites of the funeral pyres of the Alamo heroes. Though later used as a military post, the Alamo[48] was apparently first a chapel (established on a new site in 1744) of the mission of San Antonio de Valero (1718), the first of several missions established by Franciscan friars in the general vicinity.

Mission San José de Aguayo, founded in 1720 by Padre Antonio Margil and named in honor of the Marquis Miguel de Aguayo,

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[48] The word álamo is Spanish for cottonwood tree, but it is considered likely that the name was applied to the chapel after its occupation by a company of Mexican troops known as the "Alamo de Parras."

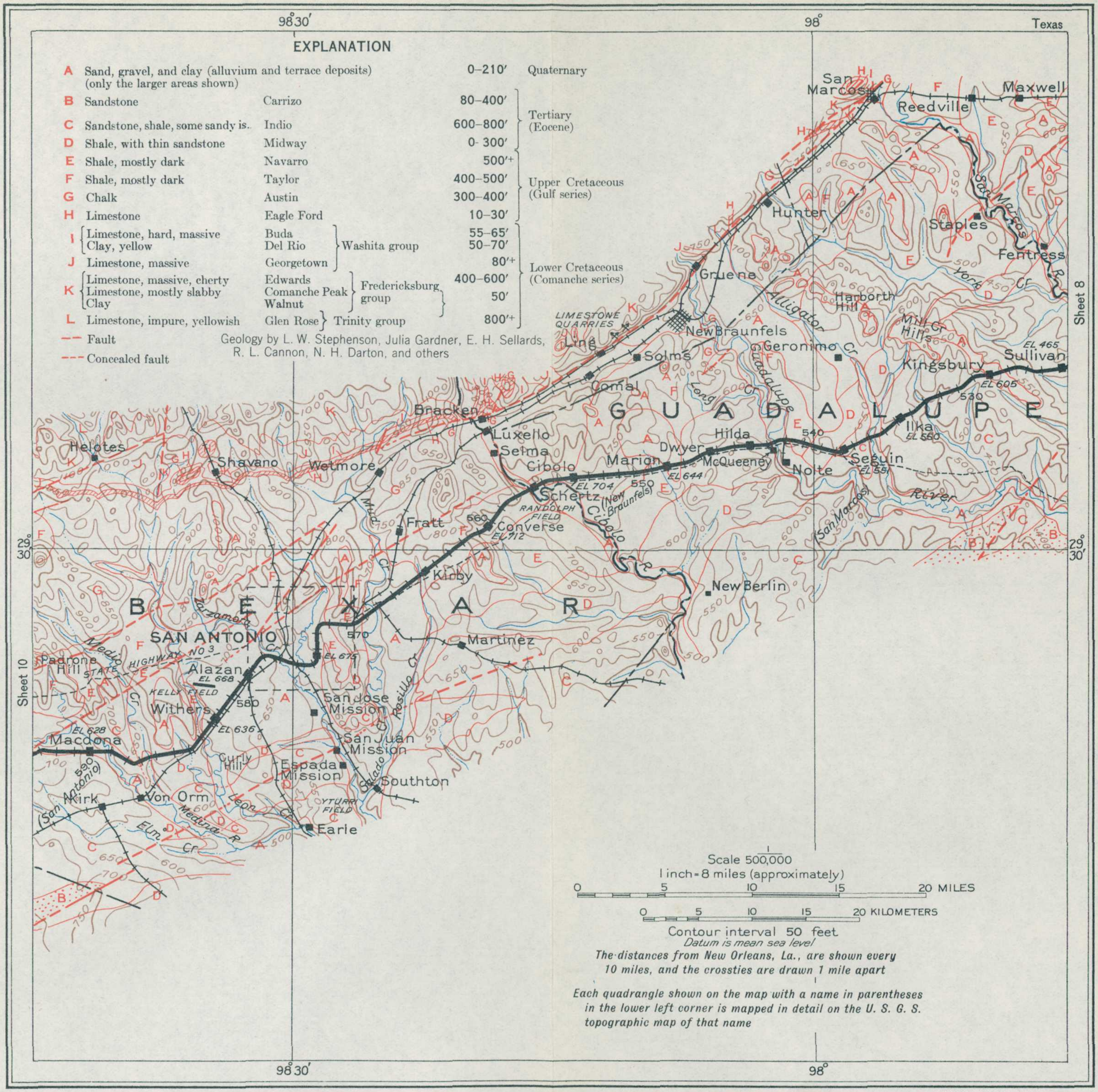
governor of Tejas, is 6 miles south of the center of San Antonio. Its south window, a fine example of stone carving, was exhibited at the World's Fair in St. Louis in 1904. Its beautiful old altar, ornamented by a noted Spanish sculptor, is now in the Cathedral of San Fernando, on the east side of the Military Plaza. This cathedral was begun in 1734, completed by a grant from King Ferdinand of Spain in 1744, and reconstructed in 1868. The mission La Purísima Concepción de Acuña, 2 miles south of the center of the city, originally established in eastern Texas, was moved to San Antonio in 1731 and is still in use. Near it in 1835 James Bowie and a party of 92 Texans won a fight against five times their number of Mexicans. Bowie died in 1836 in the defense of the Alamo. The mission San Juan de Capistrano, which was established in 1731 near the San Juan ford of the San Antonio River, was also formerly near Nacogdoches. The mission San Francisco de la Espada was originally in eastern Texas, having been the first mission established there. Founded in 1690 under the name San Francisco de los Tejas, it was abandoned three years later, reestablished in 1716 under the name San Francisco de los Neches, and transferred in 1731 to the west bank of the San Antonio River, 9 miles south of the center of the city. Aqueducts built by monks and Indians two centuries ago still irrigate the gardens at this place.

The older part of San Antonio is built on a plain of alluvial deposits, but the northern, western, and eastern parts extend onto rolling hills of Upper Cretaceous rocks. A fault with downthrow on the east side passes through the northwestern part of the city. On its west side are hills of Austin chalk, consisting largely of a soft chalky limestone [49] which has been quarried extensively for use in building, especially for houses in the older part of the city. Exposures of this material extend through part of Brackenridge Park, notably near the Sunken Gardens and Monkey Island, and in the rolling hills to the northwest, but much of the rock weathers into soil on the sloping surfaces. To the west this formation dips beneath the clays of the Taylor formation,[50] on which the western part of the city is built.

In the slopes of the gravel-capped ridges extending south from Fort Sam Houston there are exposures of clay of the Navarro formation, which extends southward to an overlap of clay and sand of the Midway formation of Tertiary age.

[49] This chalky material contains many shells of Foraminifera, minute organisms that lived in the sea water that covered this area during most of Cretaceous time. There are also many shells, including *Gryphaea aucella*, *Mortoniceras texanum*, *Inoceramus undulatoplicatus*, *Exogyra ponderosa* (upper beds), and other marine species. A 1-foot layer composed of the shells of *Gryphaea* and *Aucella* is conspicuous along the north edge of San Pedro Park. (See pl. 8, *A*.)

[50] This formation, which is about 475 feet thick, contains many fossils including various oysters such as *Exogyra ponderosa*, *E. laeviuscula*, and *Ostrea* aff. *O. diluviana*.



Topography in part from maps by U. S. Army Corps of Engineers and by U. S. Geological Survey, and in part by N. H. Darton

The most notable physiographic features in the San Antonio region are the wide plains and terraces which have been developed by erosion and deposition by streams on the surface of the soft clays of the Tertiary and Cretaceous formations. The largest plain, which lies a short distance above the narrow alluvial strips bordering the streams, extends from the San Antonio River to Leon Creek and is occupied by Kelly Field and other aviation stations. It is covered in greater part by a sheet of gravel and loam, mostly from 10 to 20 feet thick, and has an elevation of 600 to 700 feet, with gentle slope to the south. A smaller but similar plain lies between Salado (sa-lah'do) and Rosillo (ro-see'yo) Creeks, east of the city. The highest plain, which occupies the ridge between the valleys of Salado Creek and the San Antonio River and is about 100 feet higher than the adjoining area, represents the Uvalde Plain referred to on page 62 (footnote). It is capped by a sheet of gravel and loam which is well exposed in the long cut of the Missouri-Kansas-Texas Railroad in the southeastern part of the city, as shown in Plate 8, *B*, and Fort Sam Houston is also built on its smooth surface. There are many outliers of this plain farther north and west.

Not far north of San Antonio there are excellent exposures of slabby Eagle Ford limestone, Buda limestone, and Del Rio yellow clays with abundant *Exogyra arietina*, and in the hills of the Edwards Plateau, of Georgetown, Edwards, and Glen Rose limestones, which carry many distinctive fossils.

Westward from San Antonio the railroad goes south for 1½ miles and then, turning abruptly west, crosses the San Antonio River and the wide alluvial plain and skirts the east side of Kelly Field. This plain is wide and level because it is developed on the soft clays of the Upper Cretaceous. It is capped by a sheet of alluvial loam deposited by Leon Creek and other streams in relatively recent geologic time. Leon Creek is crossed just beyond Leon siding, and the low rolling hills of the Midway formation capped by gravel of the higher terrace level are traversed between Leon Creek and Medio Creek.[51]

Macdona.
Elevation 628 feet.
Population 110.*
New Orleans 590 miles.

A mile west of Leon Creek the railroad bends around the south end of a ridge, showing ledges of buff sandstone of the Midway formation, which with low dip to the west passes under the Indio formation at Medio Creek. All the lower lands from this point westward past Macdona and Lacoste (turn to sheet 10) are underlain by alluvial sand and gravel deposited by the Medina River, which is crossed a mile east of Macdona. This stream rises in the

[51] In the bank of Leon Creek about a mile north of the railroad is an excellent exposure of the unconformable contact of the Midway on Navarro sandy clay or Escondido (p. 71), a relation which is revealed at intervals up the creek to the fault that crosses the stream about 4 miles above the railroad.

Edwards Plateau, and at the head of a deep canyon about 25 miles west-northwest of San Antonio it is dammed to make Lake Medina, a large storage reservoir and an attractive resort. The dam is 164 feet high and 1,580 feet long. The water diverted into a canal some distance below the dam is carried along the ridge west of Castroville to be used for irrigation in the region south. This canal is crossed by the railroad at Pearson siding, 4 miles west of Lacoste. The Medina River along the railroad carries but little water because of the dam 15 miles above that diverts most of the flow into the irrigation canal. In an exposure of the Escondido formation in a cut about 5 miles west of Macdona there is yellow limestone at the top, 2 feet, with a thin fossiliferous layer; yellow shale, 5 feet; yellow impure sandstone, 4 inches; and yellow-brown shale, 3 feet to the base. The beds dip about 1° SW. The railroad is deflected to the south to carry it around the south end of a high ridge of Escondido shale which extends along the west side of the Medina River Valley in the Castroville region,[52] north of the railroad. The higher part of this ridge is capped by gravel of a high-level terrace, the Uvalde Plain, of which there are many remnants in the region west of San Antonio.

Lacoste.
Elevation 718 feet.
Population 300.*
New Orleans 597 miles.

From Pearson siding northwestward for 10 miles the railroad is mostly in a valley in clays with limy layers, of the basal group (Midway) of Tertiary age. The continuity of the strata is broken by several faults, mostly trending east-northeast, which bring up the underlying Escondido formation obscurely exposed at intervals.[53]

Just beyond Dunlay the railroad crosses a low ridge consisting of shales with hard sandstone layers of the Escondido formation. On both sides of the pass through which the railroad goes are plateau remnants of moderate height in which the Escondido beds are overlain by the Midway group, which is capped by old terrace gravel deposited when the drainage system of the region was about 200 feet less deep than it is at present, a feature referred to on previous pages.

Dunlay.
Elevation 994 feet.
Population 30.*
New Orleans 611 miles.

[52] Castroville was founded by and named for Count Henri de Castro, who in 1844 brought there a colony of French and Alsatians. The architecture is largely of French rural type, with sloping roofs, small windows, and batten blinds.

[53] In the region between San Antonio and Del Rio, although some of the Upper Cretaceous formations continue unchanged in character and relations, others show decided change. One of the most notable features is the development of the Anacacho limestone, 300 feet or more thick, replacing the Taylor shale, and merging westward into the Upson clay and the San Miguel formation. The Navarro shale also merges laterally to the west into the Escondido formation, which may be 700 feet thick in the Uvalde region. These changes are represented diagrammatically in Figure 6, which, however, necessarily has a greatly exaggerated vertical scale. The Midway, the lowest formation of the Tertiary system in this region, lies unconformably on the Escondido formation (western extension of the Navarro shale) with but little discordance of dip.

The gravel and sand cap of the plateau, in large part filled with caliche, is well exposed on State highway 3 a short distance south of the railway. West of the divide the railroad descends into a wide alluvial plain comprising the valleys of Quihi, Hondo, Seco, and other creeks and mostly floored with gravel and sand which hide the underlying clay of the Escondido formation. This formation, however, appears in a few hills that rise out of the plain and extend along part of its southern margin. A few miles north of the railroad the underlying formations appear in succession, for there is a general rise of the strata to the north and considerable faulting, in part with uplift on the north side. In about 15 miles the Georgetown and Edwards limestones come to the surface, constituting the Edwards Plateau, which is in view far to the north as the railroad crosses the divide northwest of Dunlay. A cross section of this region is shown on sheet 10, opposite page 69.

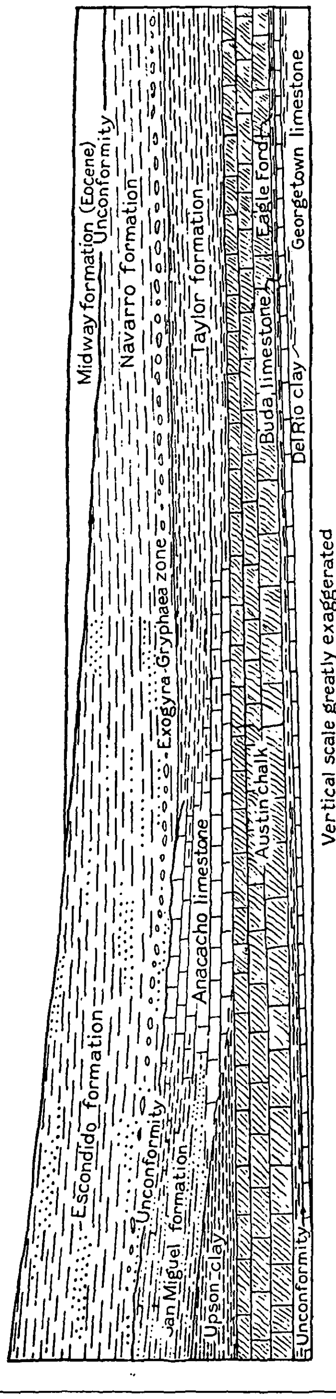


FIGURE 6.—Diagram showing changes in stratigraphy from west to east in south-central Texas, Spofford to San Antonio. (From data by L. W. Stephenson)

At Hondo (own'do; Spanish, deep) the railroad is on an alluvial plain out of which rise several low ridges of Escondido clay and sandstone. There are instructive exposures of the various formations in the shallow valleys of Hondo and Verde Creeks.[54]

Hondo.
Elevation 889 feet.
Population 2,500.*
New Orleans 622 miles.

An old Comanche Indian village was situated near Hondo, and the flint for arrowheads was obtained from pebbles, which are abundant in the neighborhood, brought by streams from the plateau of Edwards limestone to the north.

In the Hondo region and westward to Uvalde most of the land is under

[54] On Verde Creek, 4 miles northeast of Hondo, ledges of limestone at the base of the Tertiary are exposed, with characteristic fossils, on a block dropped

cultivation with varied crops, including considerable corn and cotton, and there are many cattle, sheep, and goats. Poultry raising and dairying are important industries.

D'Hanis (named after an old French settler but settled by south Germans) is on the alluvial plain, but hills of the older formations rise to the south and north.[55] To the west and south are high banks of clay of the Escondido formation, which is worked for brick and tile. Two principal terrace levels will be noted in this region, a lower one of alluvium and an upper one capped by sand and gravel (late Tertiary?). Old D'Hanis, a mile east of the station, south of the tracks, was on the early stage route from San Antonio to El Paso. Near by is a large gravel pit showing the thickness of the alluvial filling. To the south is a high hill with a cross on top, which was placed there originally as a landmark and is at present a shrine for the Mexican people of the region.

D'Hanis.
Elevation 882 feet.
Population 2,513.*
New Orleans 630 miles.

A mile west of D'Hanis the railroad crosses Seco Creek (say'co) which drains a part of the Edwards Plateau. On its banks 2 miles to the north are the ruins of Fort Lincoln, 1849–1852, once garrisoned with 141 men to keep the Comanche Indians and outlaws in check.

Beyond Seco Creek there is a long ascent on a slope of clay (Escondido) to the summit of the wide, high plateau which separates the valleys of Seco Creek and the Sabinal River (sah-bee-nahl'). This plateau, nearly 200 feet high, is heavily capped by sand with coarse gravel and boulders, in large part cemented by caliche. There are many small exposures of this capping, notably one in a gravel pit north of the tracks just east of Seco siding. It extends north to the foot of the rise to the Edwards Plateau, about 5 miles north, and to the west it slopes down somewhat and terminates at the edge of a steep down slope 11½ miles west of D'Hanis.

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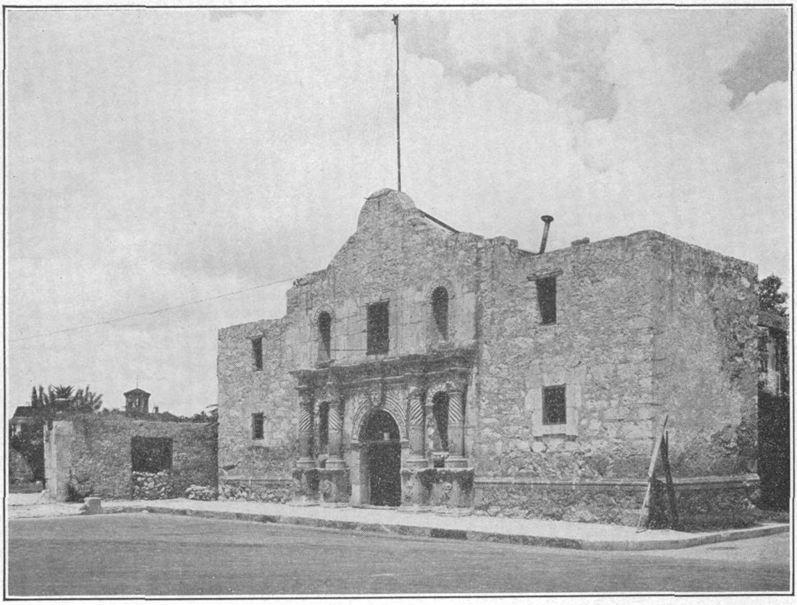
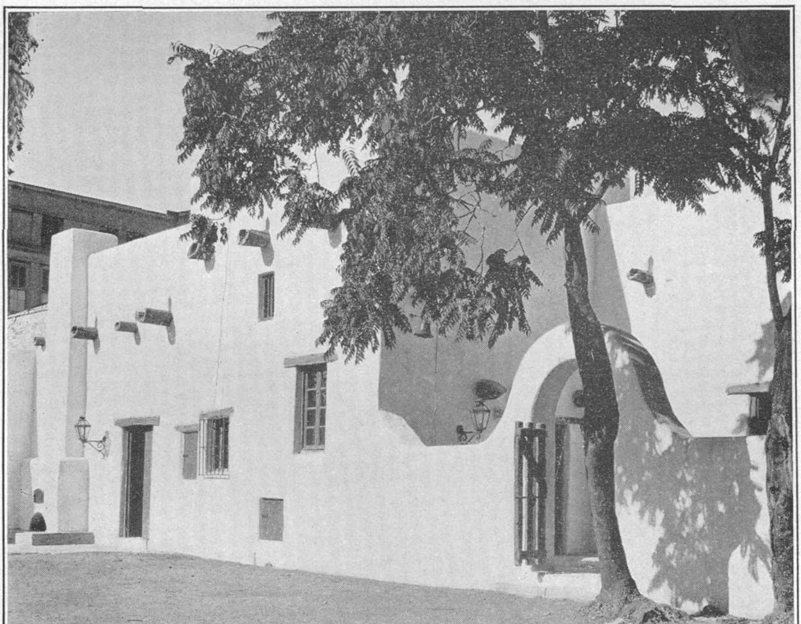
by a fault that crosses the region from northeast to southwest a short distance to the north. In slopes just north of this fault are exposures of Austin chalk, beyond which to the north are outcrops of the usual succession of Eagle Ford, Buda, Del Rio, Georgetown, and Edwards limestones, coming up in order on the moderate south dip, as shown in the cross section on sheet 10. (See table on p. 75.) Another outcrop of Midway limestone, similarly down-faulted, is reported near Quihi Creek, 9 miles northeast of Hondo. At King's water hole on Hondo Creek, 3 miles north by west of Hondo, are exposures of Anacacho limestone and overlying shale, as shown in Plate 11, *A*, and farther up the creek Austin chalk, Eagle Ford limestone, and Del Rio clay crop out. The Del Rio in this region is yellow clay carrying many *Exogyra arietina*, named from its shape, like a ram's horn (Latin *aries*, ram). The beds are considerably faulted; one fault crossing Hondo Creek about 7 miles north of Hondo between Buda limestones and Eagle Ford beds is shown in Plate 9, *B*.

[55] Seco Creek, about 3 miles north of D'Hanis, has moderately high banks of Anacacho limestone, and a short distance farther north the Austin chalk is well exposed. The beds are considerably faulted. Farther north are foothills of Austin chalk, a zone of Buda and Del Rio outcrop, and long slopes of Georgetown limestone.



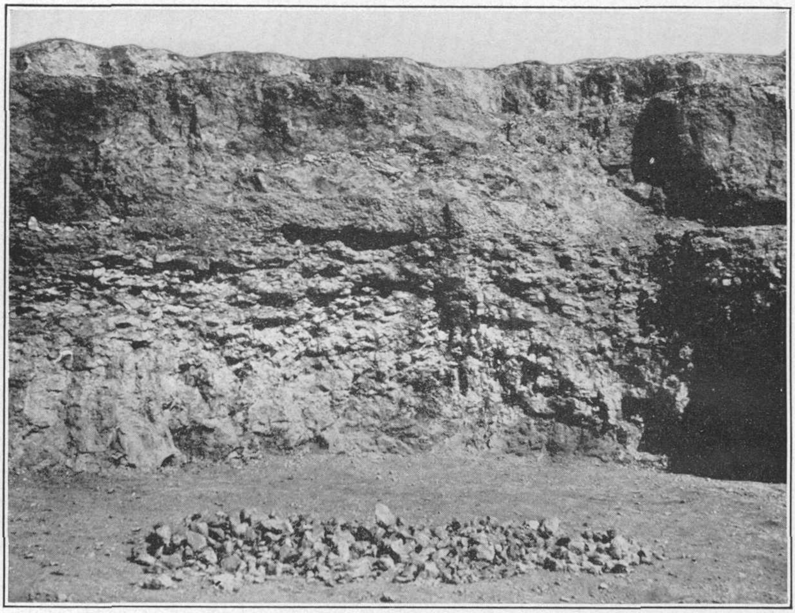
A. THE ALAMO, SAN ANTONIO, TEX.

Here in 1836 a band of 182 Texans were besieged by the Mexican Army.



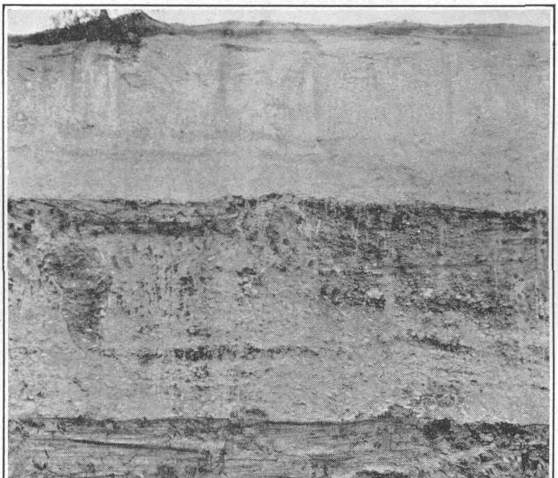
B. PALACE OF SPANISH GOVERNOR, MILITARY PLAZA, SAN ANTONIO, TEX.

Recently restored.



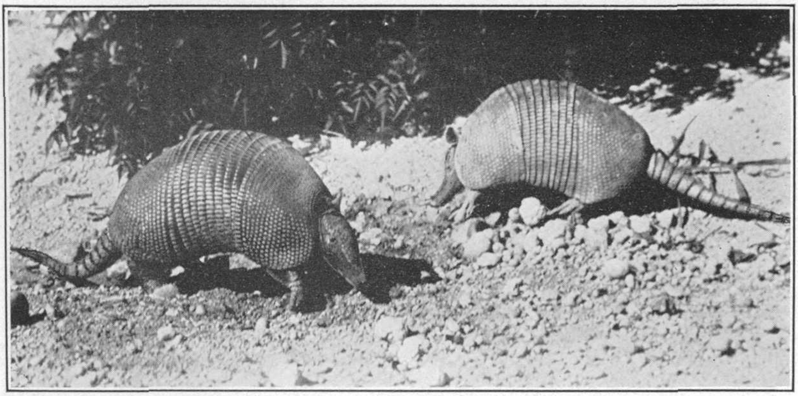
A. AUSTIN CHALK IN SAN PEDRO PARK, SAN ANTONIO, TEX.

The thick hard layer in the middle consists largely of *Gryphaea aucella*, an oyster reef of Comanche time (Lower Cretaceous). (Stephenson.)

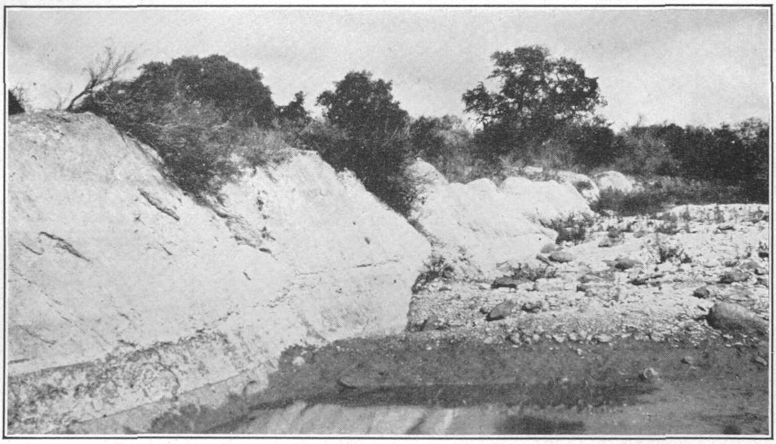


B. QUATERNARY AND EOCENE DEPOSITS IN CUT OF MISSOURI-KANSAS-TEXAS RAILROAD, IN SOUTHEASTERN PART OF SAN ANTONIO, TEX.

White caliche, 10 feet, underlain by gravel, 10 feet, and Midway shaly clay, 8 feet. (Stephenson.)

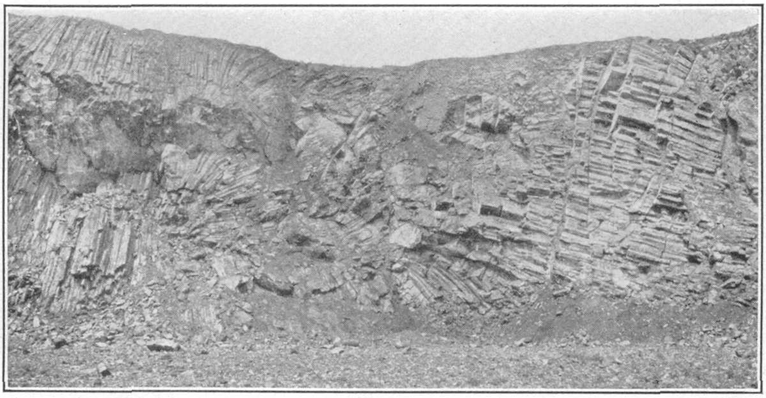


A. ARMADILLOS, ABUNDANT IN CENTRAL TEXAS



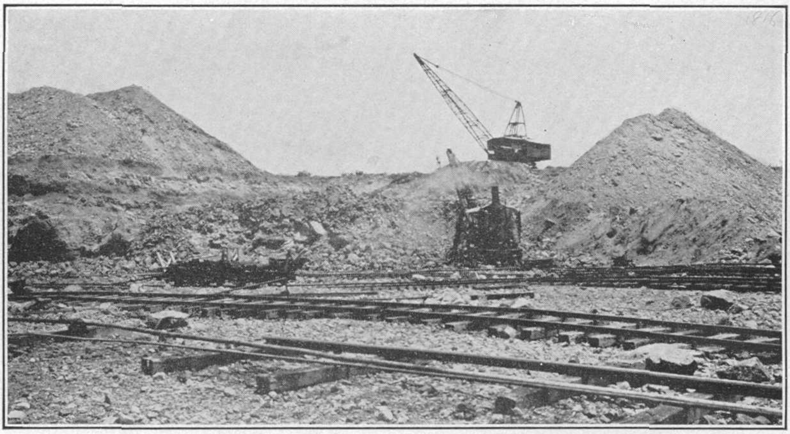
B. FAULT IN BUDA LIMESTONE ON HONDO CREEK, 7 MILES NORTH-NORTHWEST OF HONDO, TEX.

Eagle Ford beds which abutted against the fault are soft and therefore have been removed by erosion. (Stephenson.)

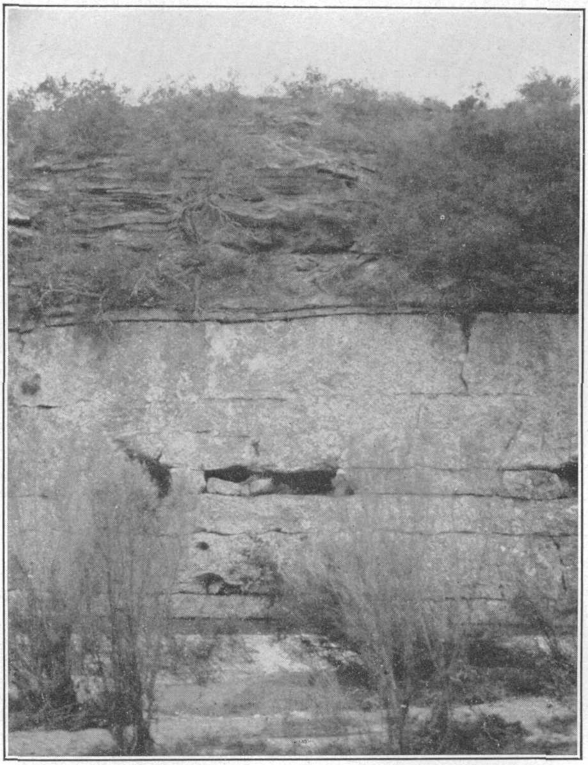


C. COLUMNAR STRUCTURE IN BASALT IN CHATFIELD HILL, WEST OF KNIPPA, TEX.

(Stephenson.)

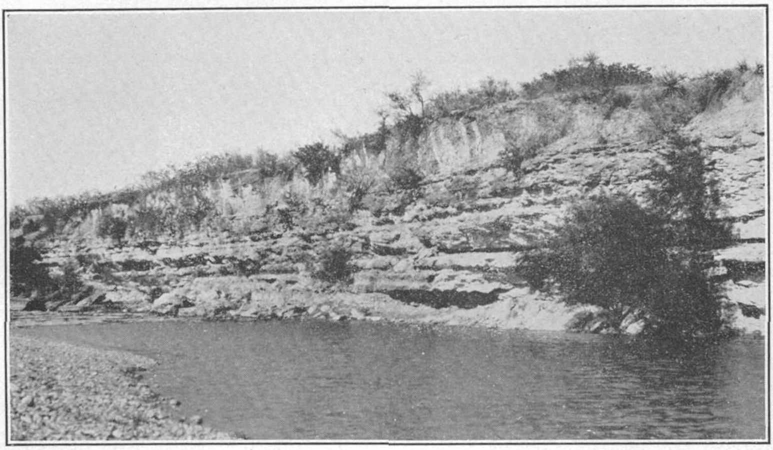


A. QUARRY IN POROUS ANACACHO LIMESTONE IMPREGNATED WITH ASPHALT, SOUTHEAST OF CLINE, TEX.



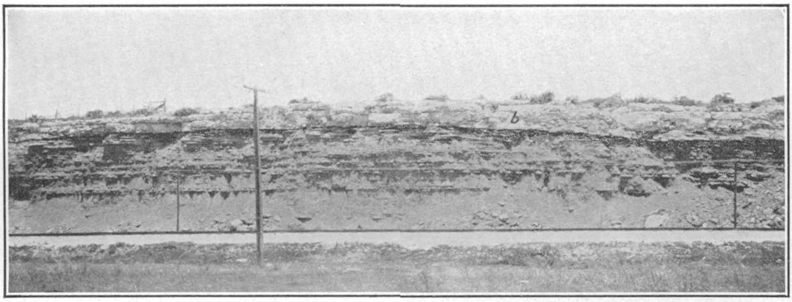
B. EAGLE FORD SLABBY LIMESTONE LYING UNCONFORMABLY ON MASSIVE BUDA LIMESTONE ON BANK OF NUECES RIVER, 4 MILES NORTHWEST OF HACIENDA SIDING, TEX.

(Stephenson.)



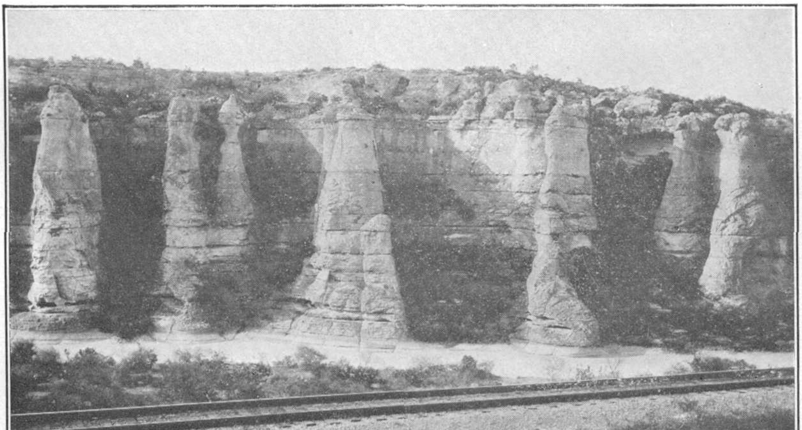
A. ANACACHO LIMESTONE AT KING'S WATER HOLE, 3 MILES NORTH OF HONDO, TEX.

Capped by 10 feet of gravel. (Stephenson.)

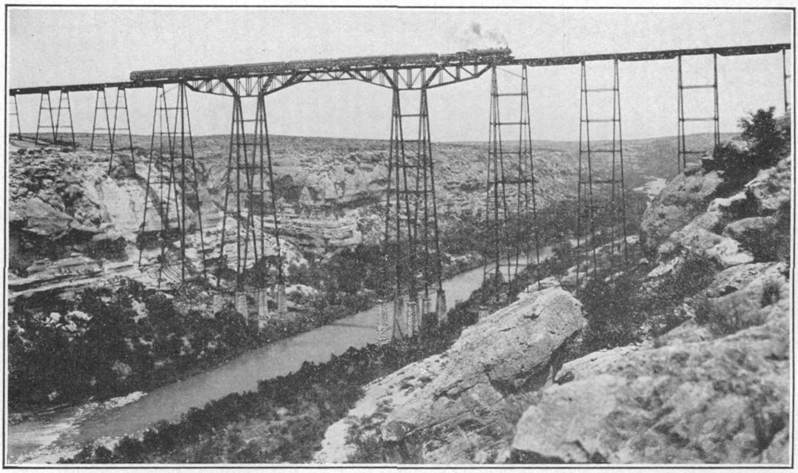


B. DEL RIO CLAY CAPPED BY BUDA LIMESTONE (*b*) IN RAILROAD CUT HALF A MILE WEST OF COMSTOCK, TEX

Looking north.

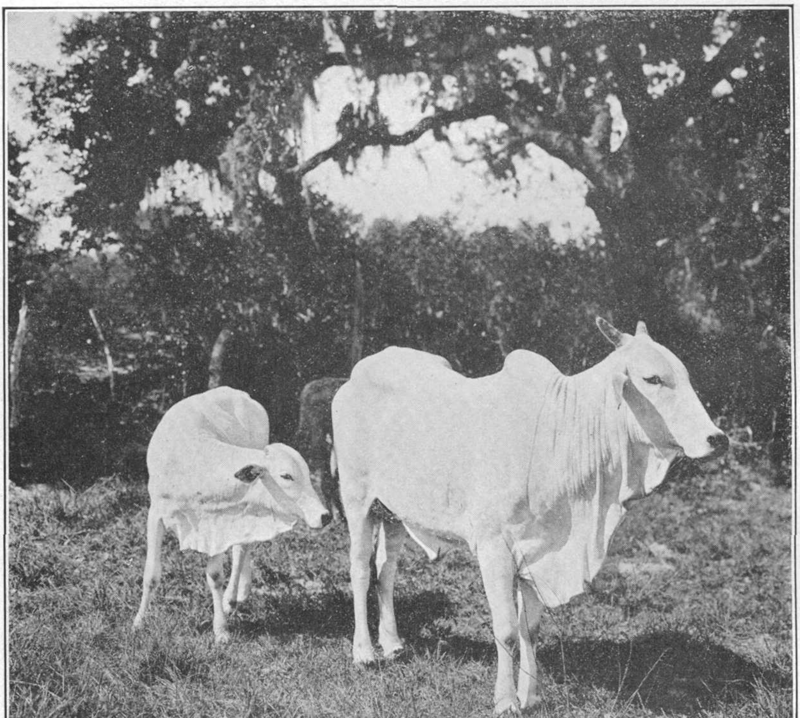


C RECESSES AND BUTTRESSES IN GEORGETOWN LIMESTONE, CASTLE CANYON, DEVILS RIVER WEST OF DEL RIO, TEX.



A. RAILROAD BRIDGE OVER CANYON OF PECOS RIVER, 12 MILES WEST OF COMSTOCK, TEX.

The walls are Georgetown limestone lying nearly horizontal.



B. BRAHMA CATTLE

Bred and crossbred extensively in southern Texas because of their ability to withstand scarcity of water and pasture.

Sabinal (sah-bee-nahl′) is on a sand and gravel plain that borders and extends west from the Sabinal River, which is crossed by the railroad a mile west of the station. On this stream there is an almost continuous succession of exposures of the strata of Upper Cretaceous age, beginning with low cliffs of Anacacho limestone south of the railroad.[56] The name of the place is derived from the word "sabina (sa-bee′na)," the Spanish name for juniper, misapplied by the Mexicans to the cypress tree, of which there is a small group on the Sabinal River a mile west of the station.

Sabinal.
Elevation 956 feet.
Population 1,586.
New Orleans 643 miles.

The Blanco River, which is crossed 4 miles beyond the Sabinal River, carries but little water except in times of freshet. Just west of it are exposures of alluvial sand and gravel containing much caliche, and the ridge near Yucca is one of the numerous remnants of an old gravel-capped high terrace in this general region.

A mile southwest of Knippa is a prominent knoll known as Chatfield Hill, caused by a mass of hard diabase which has been intruded in the Cretaceous strata. It is similar to many other igneous masses that are more or less prominent topographic features in the surrounding region and for a long distance west. These igneous rocks have come in a molten condition through cracks from a deep-seated source and either formed irregular conical masses or spread out in "sills" or layers between the sedimentary strata. They lift the overlying beds and in many places flex or break them irregularly. The mass near Knippa is extensively quarried for road metal just south of the railroad. A notable feature seen especially in the upper part of the quarries is the columnar structure of the rock, such as is developed in many intruded igneous masses (notably in the Palisades of the Hudson opposite New York City). This structure is developed by shrinkage in cooling, both in intrusive masses and in many lava flows. A portion of one of the quarries is shown in Plate 9, *C*. Just north of Chatfield Hill the railroad crosses two main branches of the Frio River (free′o), which comes from the Edwards Plateau. The size of the bridges at this place indicates that provision is made for the passage of a great body of water in time of freshet. A short distance farther west are conspicuous limestone hills a mile or so north of the railroad which consist of an upfaulted block of Georgetown limestone. In the adjoining foothills are extensive outcrops of

Knippa.
Elevation 985 feet.
Population 150.*
New Orleans 654 miles.

[56] The Anacacho limestone crops out at intervals to the north for 4 miles, with a short interruption caused by a low arch and fault that reveal the underlying Austin chalk. This chalk also appears in the river banks and on adjoining slopes 4 miles north of Sabinal and above. At a point 8 miles north of Sabinal faults bring up Eagle Ford, Buda, and Del Rio beds, and finally the Georgetown and underlying limestones come to the surface.

Eagle Ford and Buda limestones and Del Rio clay, the Eagle Ford beds being exposed for some distance along the railroad near Ange siding. Big Mountain, a mile northwest of Ange, is made up of Georgetown limestone. The Cretaceous strata in this vicinity are penetrated by igneous masses, some of which, on account of their hardness, crop out prominently. (Turn to sheet 11.)

The train passes about 2 miles north of Uvalde, with which the station is connected by a paved boulevard. Uvalde is the name of a Spanish officer who with 20 soldiers defeated many times that number of Comanches. The region is mostly a smooth alluvial plain in which rise many small ridges and knobs of Cretaceous strata or the igneous masses that penetrate them. There are also higher terraces of considerable extent capped by gravel, which mark an earlier stage of the topographic development of the region. Not far north is the edge of the Edwards Plateau,[57] a highland consisting of a wide area of the hard Georgetown and Edwards limestones lying nearly horizontal and deeply trenched by many rivers and creeks.

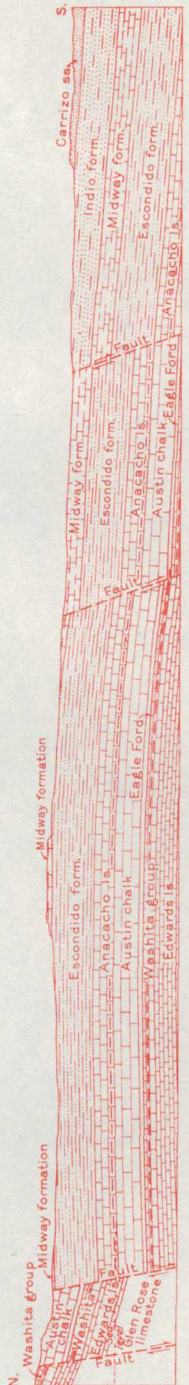
Uvalde.

Elevation 929 feet.
Population 9,286.
New Orleans 664 miles.

Not far north of Uvalde and at intervals to the east and southeast are exposures of Eagle Ford limestone, Buda limestone, and the yellow Del Rio clay. Along or not far from the railroad to the south are small outcrops of Austin chalk, and from 10 to 20 miles southwest and south are exposures of sandstone and clay of the Indio formation (Tertiary), in places underlain by Midway formation. Some of the general relations are shown in the cross section on sheet 11. The stratigraphic succession is given in the following table:

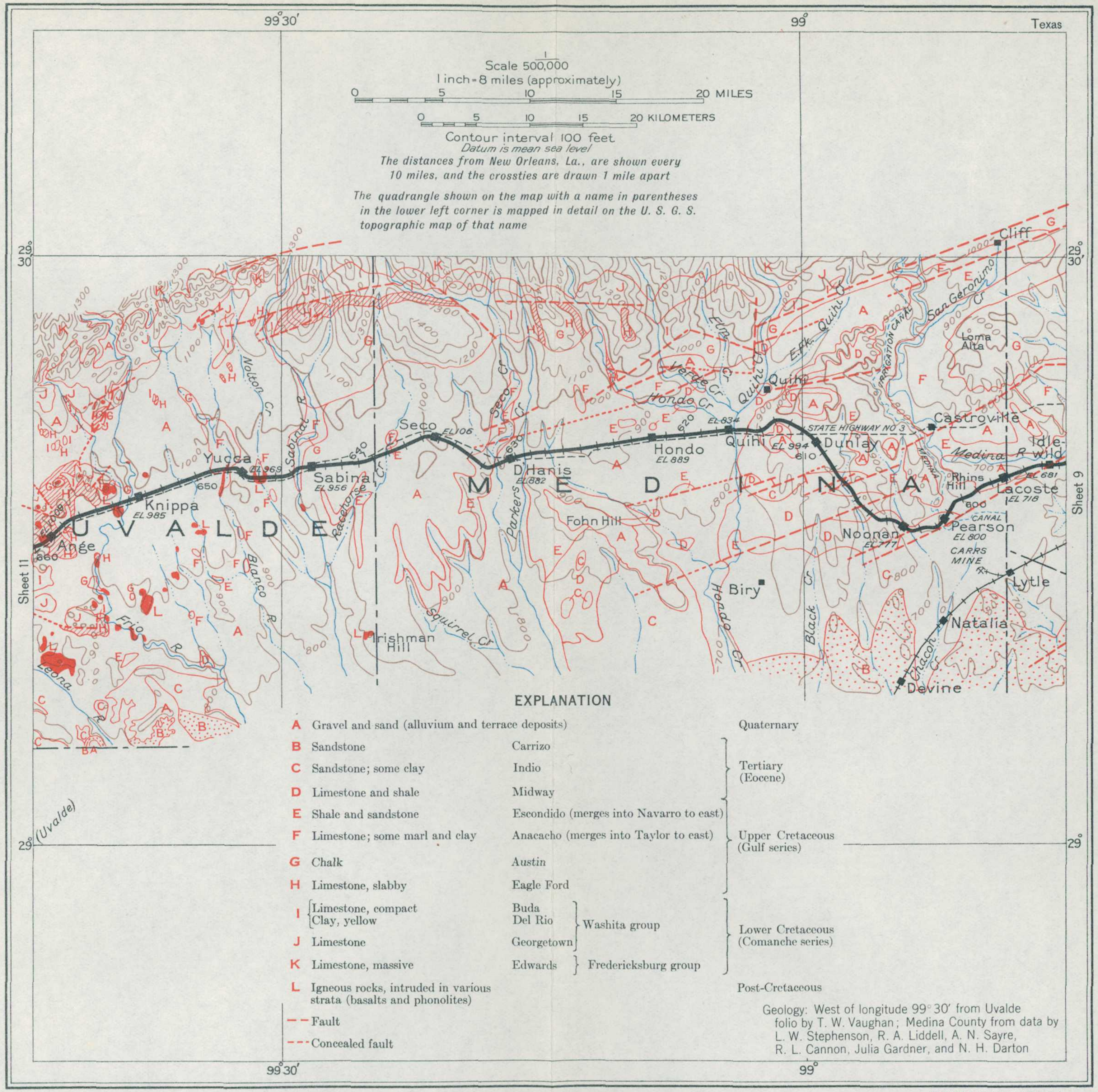
[57] The Edwards Plateau constitutes a large part of central Texas and near Big Spring is overlapped by the High Plains without much topographic break. The late Tertiary deposits of the High Plains were spread on a plain of the limestones of the Edwards Plateau but did not cover the portion south of latitude 31°. The Edwards Plateau extends west to the Marathon uplift and east to the vicinity of San Antonio and Austin. In larger part it is capped by 100 feet or more of Georgetown limestone (Washita group), the Edwards limestone appearing in the slopes of the valleys and on some of the areas from which the younger limestone has been removed.

The sharp rise at the eastern and southern edge of the Edwards Plateau, usually referred to as the Balcones escarpment, owes its prominence to the presence of the hard limestone, in places uplifted by faults but generally rising rapidly on the dip. Parts of the plateau are so deeply trenched as to present many isolated mesas and buttes. (Mesa (may'sah), a Spanish word meaning table, is applied to a flat-topped butte or hill; one that has a sloping tabular surface is called a cuesta (kways'tah).)



DIAGRAMMATIC SECTION ACROSS MEDINA COUNTY NEAR LONGITUDE 99° (SAYRE)

Quaternary gravels and sands not shown



Topography east of longitude 99° 30′ from sheets 444 and 467, Progressive Military Map, Corps of Engineers, U S Army

WILLIAMS & HEINTZ CO., WASH., D. C.

Formations of central Texas

[Vaughan and others]

	Formation	Character and notable fossils	Thickness (feet)
Pliocene and Pleistocene.	Alluvium	Sand and gravel; terraces along streams	0-70
	High terraces	Gravel with much chert; caps hills and old terraces	0-80
	Unconformity		
Eocene (early Tertiary).	Indio	Bedded and cross-bedded sands and sandstones and dark-colored clays, for the most part nonmarine and in places carbonaceous; *Ostrea multilirata*. Of Wilcox age.	800-850
	Midway	Concretionary gray sand and sandy clay with no observed fossils, in upper 10 to 20 feet, followed below by glauconitic sands, in places loosely indurated, with a calcareous cement and fine yellow calcareous pack sand containing *Cucullaea, Venericardia, Turritella*, and *Enclimatoceras*.	10-120
	Unconformity		
Gulf series (Upper Cretaceous).	Escondido	Shale and calcareous sandstones, coarse and fine; *Ostrea cortex, Sphenodiscus pleurisepta*.	700
	Anacacho	Impure limestone and marl; *Echinocorys texana, Exogyra ponderosa, Liopistha bella, Baculites asper, Scaphites hippocrepis*. Carries asphalt in places.	0-350
	Austin	Chalk, white and yellow; *Gryphaea aucella, Inoceramus undulato-plicatus, Mortoniceras texanum*.	350-400
	Eagle Ford	Shale and flaggy limestone, mostly impure, *Inoceramus labiatus*.	150(?)
	Unconformity		
Comanche series (Lower Cretaceous).	Buda	Limestone	60-75
	Del Rio	Yellow clay; *Exogyra arietina*	30
	Georgetown	Limestone; *Kingena wacoensis*	50-150
	Edwards	Limestone, mostly hard, massive, cavernous; much flint in places.	500+
	Comanche Peak	Limestone, yellow, impure; many *Exogyra texana*	60

There is considerable agriculture about Uvalde, but the climate approaches the semiarid, with an annual rainfall of approximately 25 inches. Although there is usually a short rainy season in the spring or early summer and another in the autumn, most of the streams are dry for the greater part of the year. Extensive pastures sustain many cattle, sheep, and goats. In places there is an extensive growth of "prickly pear," or nopal (no-pahl′), which is used rather extensively for forage after the thorns are singed off. A large amount of honey is produced in this region, aided greatly by the presence of various plants such as mesquite and huajillo (wah-hee′yo), which yield much nectar for the bees. There is a notable spring on the Leona River a mile below Uvalde, which is locally estimated to furnish about 7,000,000 gallons a day, but the volume varies somewhat with the seasons. The water is used for irrigation.

In the region between Uvalde and Del Rio portions of the Rio Grande Plain, which is a western extension of the Gulf Coastal Plain, reach the Southern Pacific line in places notably about Spofford and westward. The lower lands are mostly level and the valleys are shallow. Smooth surfaces prevail about Spofford and westward to Del Rio. The Edwards Plateau lies some distance north, beyond hills and sloping ridges of Austin chalk and Eagle Ford and other limestones, and many buttes or knobs of hard, igneous rocks project prominently above the general surface.

From Uvalde Station past Hacienda siding (ah-see-ane′da), nearly to the Nueces River, the railroad is on a smooth plain of alluvium. There is a notable exposure of the unconformable contact of the Eagle Ford slabby limestone on the massive Buda limestone on the bank of the Nueces River 4 miles northwest of Hacienda siding, as shown in Plate 10, *B*. The Nueces River is in a shallow valley also floored by alluvium, with rocky banks at intervals. In dry weather it carries little water, but farther south it is a large watercourse, entering the Gulf of Mexico at Corpus Christi. In the days when Texas was a part of the Republic of Mexico, as a department of Coahuila, the Nueces River was its southern boundary, between it and Tamaulipas and Coahuila, both of which straddled the Rio Grande; on the west Texas adjoined the States of Chihuahua (che-wah′wa) and Nuevo Méjico as far as the Red River. The available geographic data of those times were so few, however, that the contemporary maps were greatly distorted as to locations and distances. Under the Republic the wide area between the Nueces and the Rio Grande, long in dispute between Texas and Mexico, was a no man's land, roamed over by Comanche and other Indians and by many outlaws.

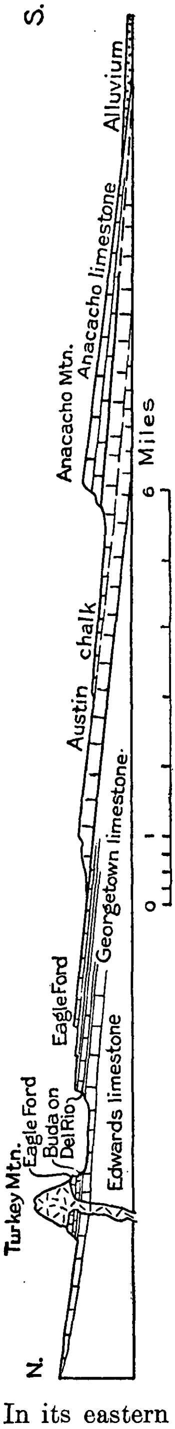


FIGURE 7.—Sketch section from Turkey Mountain south through Anacacho Mountain, Tex.

West of the Nueces River the railroad ascends into a region of low buttes and ridges of Austin chalk with scattered small outcrops. Trees are rare.

Cline.

Elevation 997 feet.
Population 40.*
New Orleans 683 miles.

Lewis Hill to the north and Obi Hill to the south are igneous, intrusive masses (basalt), and larger bodies of these rocks constitute buttes farther south. The chalk is covered by loam and sand (alluvium) near Cline and for some distance west, but it is visible in adjacent slopes. Eight miles southeast of Cline are extensive quarries in the Anacacho limestone, which there carries a large proportion of asphalt. (See pl. 10, *A*.) This material is used for paving, and asphalt melted out of the rock is used for paint and other purposes. It is brought to Cline by a branch railroad.

Southwest of Cline rises the prominent Anacacho Mountain, which is formed by the hard Anacacho limestone dipping south, as shown in Figure 7. In its eastern part here, as in the region farther east, the Anacacho limestone lies on Austin chalk, but in its western part a sheet of Upson clay intervenes between them. North of the mountain are long slopes of Austin chalk succeeded by slabby buff Eagle Ford limestone, which thickens considerably to the west. About 12 miles north of Odlaw siding is Turkey Mountain, a plug of intrusive igneous rock in part capping a mound of Eagle Ford, Buda, and Del Rio beds. The railroad is on Austin chalk from Odlaw west for several miles. At Chacon Creek (cha-cone′), southwest of Anacacho siding, Anacacho Mountain ends through a rapid thinning of the limestone or through change of its upper member into softer rocks of the San Miguel formation and also of its lower member into Upson clay.

Spofford.

Elevation 1,009 feet.
Population 40.*
New Orleans 705 miles.

From Spofford a branch of the Southern Pacific runs to Eagle Pass (old Fort Duncan), an important town on the Rio Grande, 34 miles south. The railroad here is on the broad Rio Grande Plain, developed on the upper part of the Austin chalk, overlain by a thick deposit of sand and gravel with much caliche, a covering that extends to and beyond Amanda siding. The chalk is revealed on Pinto Creek near Pinto siding, in a quarry 3 miles beyond Pinto, and also in the arroyos to the south, which cut deeply to reach the Rio Grande. Ten miles north of Spofford, just south of Brackettville, on State highway 3, is Fort Clark, which was established in 1852 to protect travelers on the old trail. The fort was named from Maj. John B. Clark, United States Army. In it have been stationed General Gorgas when he was a second lieutenant, General Bullis, General Shafter, and General Pershing. In 1931 there were 386 soldiers and 44 officers there. The fort is near the Las Moras Springs (Spanish, moras, blackberries), which ordinarily have an average flow of about 22,000,000 gallons a day. (Meinzer.) Still farther north is Las Moras Mountain, due to an intrusion of igneous rock which has been forced up in molten condition through the Cretaceous strata. Other conspicuous igneous masses near by are Elm Mountain, 10 miles northwest of Pavo siding, and Pinto Mountain, 10 miles northwest of Brackettville.

In the region between Spofford and Del Rio the formations traversed are as follows:

Formation	Character	Thickness (feet)
Austin	Chalk and soft massive limestone	350
Eagle Ford	Shale and slabby limestone, buff	150
Buda	Hard massive limestone	60
Del Rio	Buff clay, hard layers, with many *Exogyra arietina*	60
Georgetown	Massive limestone	200+

Although the general regional dip of the strata is to the east and southeast, they are flexed by an anticline with about 150 feet of uplift the axis of which trends west by north. It extends from Sycamore Creek, 2 miles south of Amanda siding, to the San Felipe Valley, a few miles north of Del Rio, the axis passing about half a mile south of Johnstone siding.[58]

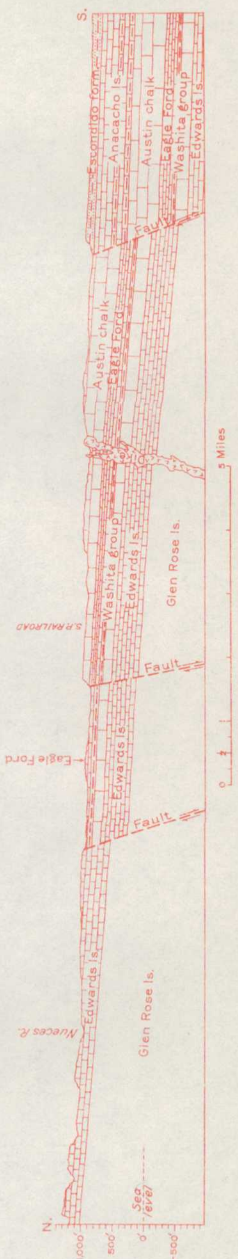
Mud Creek, crossed between Standart and Amanda sidings, is mentioned in many narratives of travel on the old trail from San Antonio west, which was near the present railroad line in this vicinity. A mile west of Amanda, on the descent to Sycamore Creek, there is a 10-foot cut in gravel and sand, which reveals the character of the deposit that covers the wide plains extending to Spofford and far to the north and south. The underlying Eagle Ford beds are exposed in a small cut 1½ miles west of Amanda. As indicated by the extensive bridge by which it is spanned, Sycamore Creek is a mighty stream in time of freshet. (Turn to sheet 12.) The cap of sand, gravel, and caliche begins again west of this creek and covers the plateau to a point within 3 miles of Del Rio. It lies on Buda limestone, which is exposed in several shallow valleys. On its western edge, a few miles east of Del Rio, is a large "tank farm" of the Mid-Kansas Oil Co., with a capacity of 80,000 barrels supplied from oil fields far to the north by pipe line. Just beyond this place there is a steep down grade on buff clays of the Del Rio formation capped by the Buda limestone. These strata constitute bluffs 50 to 100 feet high extending far to the north and south from the railroad grade and forming the east slope of the Rio Grande Valley; it is from the exposures in these bluffs that the Del Rio clay was named. In the bottom lands not far west of the Buda-Del Rio bluff is San Felipe Creek, which has cut a shallow trench in the underlying massive limestone (uppermost Georgetown). This limestone is overlain widely by gravel, sand, and caliche of the alluvial plain on which Del Rio is built, which extends to the Rio Grande 2 to 3 miles distant.

Del Rio.

Elevation 963 feet.
Population 11,693.
New Orleans 742 miles.

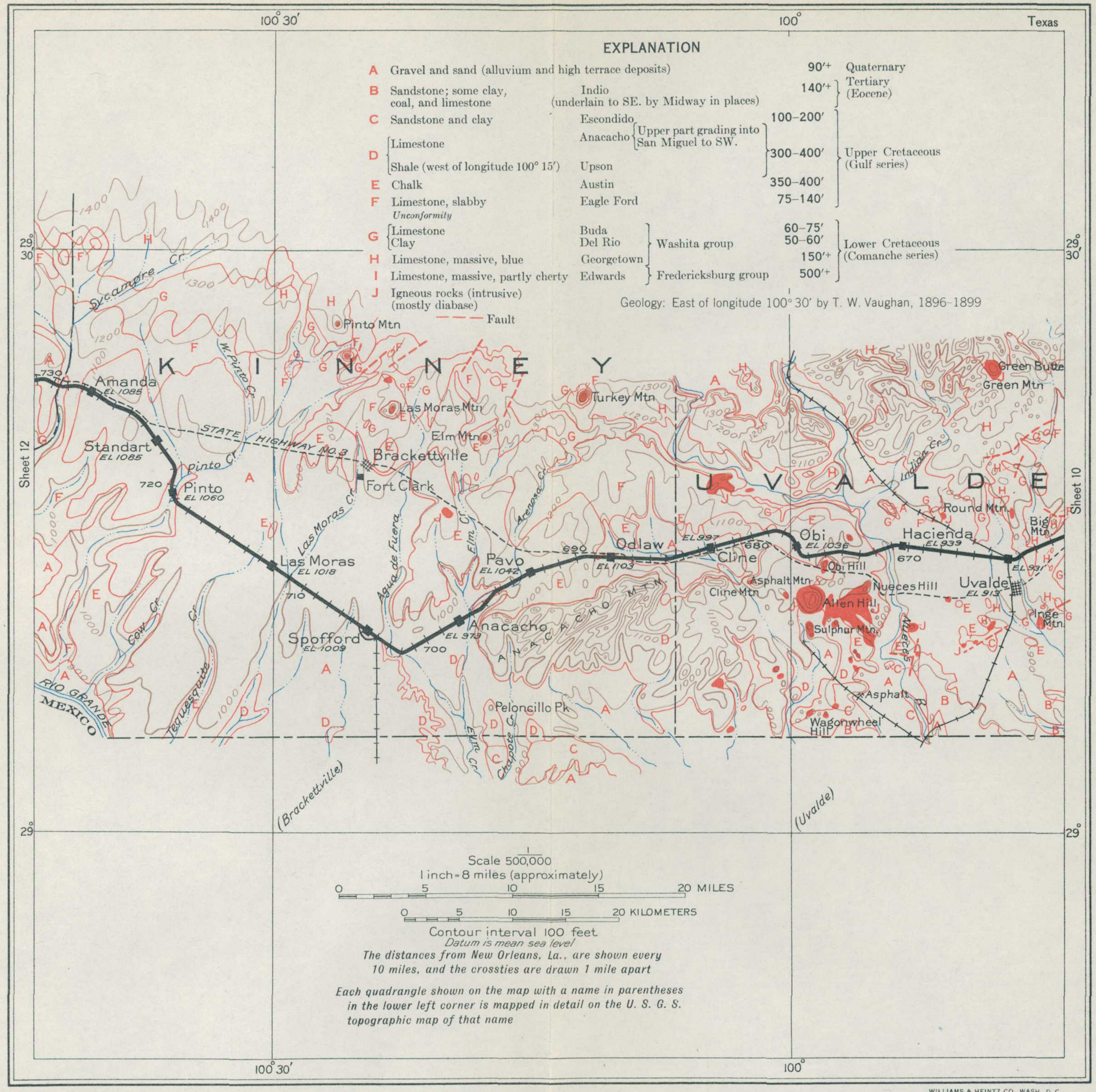
Del Rio is on the frontier, for there are no other large towns to the west until El Paso is reached. It is a commercial center for a wide district of stock, sheep, and goat raising, wool, mohair, and agricultural interests, and a port of entry from Mexico by way of Villa Acuña (vee′ya a-coon′ya) on the Coahuila side of the Rio Grande, with which it is connected by a long bridge. On the alluvial plain about Del Rio there is considerable agriculture sustained by irrigation,

[58] A 2,800-foot boring 3 miles east of Amanda siding is thought to have reached the base of the Edwards limestone at a depth of about 2,000 feet. A boring 6 miles north of Del Rio started in Del Rio clay and penetrated shale and gray limestone of supposed Pennsylvanian age below 2,175 feet. This indicates a thickness of about 2,235 feet for the Comanche series, which thickens to the west from the Uvalde-Brackettville region. Water-bearing beds were found in both holes (Stephenson).



DIAGRAMMATIC SECTION ACROSS UVALDE COUNTY ABOUT 8 MILES WEST OF UVALDE (SAYRE)

Quaternary gravels and sands not shown



Topography: U. S. Geological Survey quadrangle maps and Del Rio sheet 423, Engineer Corps, U. S. Army for the climate is too arid for dry farming. Some of the water is obtained from San Felipe Spring, in the eastern part of the city, which has a flow of 50,000 gallons a minute (Meinzer). It issues from the top of the Georgetown limestone, probably rising through crevices from sandy beds at the base of the limestone or from sandstone of the underlying Trinity group. The original settlement here, owing its location to the great spring, was called San Felipe. Here an old Mexican trail joined the trail connecting El Paso with San Antonio and New Orleans. Turning eastward it crossed Mud Creek, 16 miles east of Del Rio, and went on through Fort Clark, Uvalde, Castroville, and San Antonio. To the west it reached the valley of the Devils River at Fort Hudson, considerably above its mouth, thus avoiding the deep canyons of the Devils River and Pecos River northwest of Del Rio. (See p. 80.)

Not far west of Del Rio the Coastal Plain gives place to the Plateau province as the hard limestones of the Comanche series rise to the surface. For the first few miles the railroad crosses the alluvial river flat, reaching the bank of the Rio Grande at McKees siding. Here the valley develops into a shallow canyon which deepens toward the west as the massive Georgetown limestone gradually rises and presents cliffs along the river bank. The railroad follows the river to a point about 15 miles above Del Rio, where Castle Canyon, the mouth of the Devils River Canyon, affords a natural gateway to the mouth of California Creek, which breaks the west wall of the Devils River Canyon near milepost 395. The canyon scenery in this vicinity is striking, the high walls of massive Georgetown limestone [59] presenting a variety of picturesque erosional forms, some of which are shown in Plate 11, *C*. The fluted columns and recesses in the limestone are especially impressive, and there are many caves which afforded shelter and hiding places for the Indians who formerly inhabited the region and left hieroglyphs on the cliffs and cavern walls. These caves are now the resort of bats; in some of the smaller ones bees store large supplies of honey. Washita fossils have been collected nearly to the bottom of the canyon of Devils River, where the top of the Edwards limestone is exposed. A conspicuous feature at Devils River station is the power plant that generates power for Del Rio and

Devils River.
Elevation 955 feet.
Population 140.*
New Orleans 757 miles.

[59] According to Dumble there is at the base of the Devils River section a sandy water-bearing limestone which is tapped by wells on surrounding plateaus. The overlying massive limestones making the great cliffs carry *Pecten texanus* Roemer (at base), *Pervinquieria leonensis* Conrad (70 feet higher), *Kingeana wacoensis* Roemer, and at the top a bed with many large *Caprinula? crassifibra* Roemer, overlain by marly beds with other Washita fossils and a more massive bed which extends to the base of the Del Rio clay farther east.

many other places. The workers of the power plant are housed in a very attractive cottage village on top of the cliff.

The Devils River is a remarkably clear and constant stream which flows for many miles in a deep limestone canyon. It has its origin in great springs not far north of the railroad; the clear sparkling water flows down the Rio Grande in a stream which for many miles keeps separate from the muddy water of the main river.

In the valley of the Devils River about 8 miles above its mouth was old Fort Hudson, an important military post in the early days, on the trail from San Antonio and San Felipe. North from Fort Hudson one trail followed the valley of the Devils River to Beaver Lake, thence crossed the ridge to Howard's Well, on Howard Creek, and went over the divide to Camp Lancaster, on the Pecos River, beyond which it joined the Emigrant or Butterfield stage route from San Angelo to Fort Stockton. A trail westward from Fort Hudson followed more nearly the present line of the railroad through Camp Bullis, Meyer's Spring, and Langtry to Peña Colorada, near Marathon.

On leaving Devils River the railroad ascends the valley of California Creek on a moderately steep grade and thence, turning westward, climbs nearly 700 feet in a distance of about 25 miles, to a divide at Rona siding.[60]

In this region there is considerable change in vegetation, and the country looks more "western." The climate is more arid than in the region east of Uvalde; trees cease on the upland, and the bushes are smaller and more widely spaced. The principal plants that continue are mesquite, huisache, and yucca. Sage, palofierro, Spanish bayonet, lechuguilla, covillea, beargrass (*Nolina*), sotol, ocotillo, and maguey begin to be noticeable.[61] There are also many annuals, most of which flower conspicuously when there is rain. Large numbers of sheep, goats, and cattle are raised.

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[60] In this ascent the top of the Georgetown limestone is reached near Feely siding, and the slopes on each side of the valley afford many outcrops of the overlying Del Rio clay, about 75 feet thick, capped by Buda limestone, which makes a cliff. Just southwest of Feely siding is a fine exposure of the abrupt contact of slabby tan-colored Eagle Ford limestone on massive light-colored Buda limestone. The plane of contact represents an unconformity with a considerable hiatus in time, but there is no noticeable difference in the attitude of the beds, there having been uplift without flexing. Beyond Cabra siding a small doming of the strata brings the Del Rio clay and Buda limestone prominently into view, and these beds are also exposed in many cuts to and beyond Comstock (nearly to milepost 416). The exposures near this town present another low dome which has the massive limestone at the top of the Georgetown bared in its center.

[61] This flora is described by W. L. Bray (Vegetation of the Sotol country in Texas; Texas Univ. Bull. 60, 1905).

There is a striking exposure on the north side of the track just beyond Comstock in which Del Rio yellow clays are capped by Buda limestone, as shown in Plate 11, *B*. The Del Rio clay at all places contains thin layers of hard, dark limestone carrying an abundance of *Exogyra arietina*, the characteristic fossil.

Comstock.

Elevation 1,546 feet.
Population 180.*
New Orleans 776 miles.

A short distance beyond milepost 416 (3 miles beyond Comstock) the outcrop of Eagle Ford limestone begins, and this formation caps the rolling country about Rona and Viaduct. From the highlands in this vicinity there are excellent views of the Burro Mountains, in Mexico (State of Coahuila), 15 miles or more to the south. The Eagle Ford beds in this region are impure slabby limestones of pale-reddish tint, highly characteristic in aspect. They are beautifully layered and in places show crumples and faults. From Viaduct siding the railroad descends across the Eagle Ford beds and Buda limestone and reaches the platform of massive Georgetown limestone, in which the canyon of the Pecos River is cut. Underlying the Georgetown is the Edwards limestone. (See pl. 12, *A*.) The railroad crosses this impressive canyon on a bridge 2,184 feet long (middle span 185 feet), built in 1890, noted for its height (321 feet) and the view that it affords. The railroad when first constructed, went west from a point near Comstock and, deflecting to the left, passed into the canyon of the Rio Grande to cross the Pecos River at its mouth; thence it climbed from a side canyon of the Rio Grande to the present site of Shumla. It was on this part of the line that construction from the east and from the west made their junction on January 12, 1883, at a point 2½ miles west of the Pecos Bridge, or 8 miles east of Shumla.

The Pecos River rises in the high ridges of the Sangre de Cristo Mountains, a part of the Rocky Mountain system, in north-central New Mexico, and empties into the Rio Grande about 4 miles below the railroad bridge, a short distance below the Pecos Bridge on Highway 3. Its length is about 600 miles. The portion of the State lying west of the stream is called trans-Pecos Texas. Apparently the first white man to visit this section was Cabeza de Vaca, in his wanderings across Texas in 1528 to 1536. In 1541 the Pecos was crossed far above this point by Coronado on his expedition in search of the city of Quivira. He noted in the region many buffalo but only a few roving Indians. Later the Pecos was crossed by Espejo on his return trip into part of the region discovered by Coronado, and he called it Rio Vaca (Cow River). In 1590 Castaño de Sosa christened it the Rio Salado because he found it salty in places. West Texas was the home of the Apache Indians and later of their bitter enemies, the Comanches, who came down from Wyoming about 1700. The Indians obtained food and clothing from the buffalo, great herds of which roamed the plains, blocking caravans and even railroad trains.

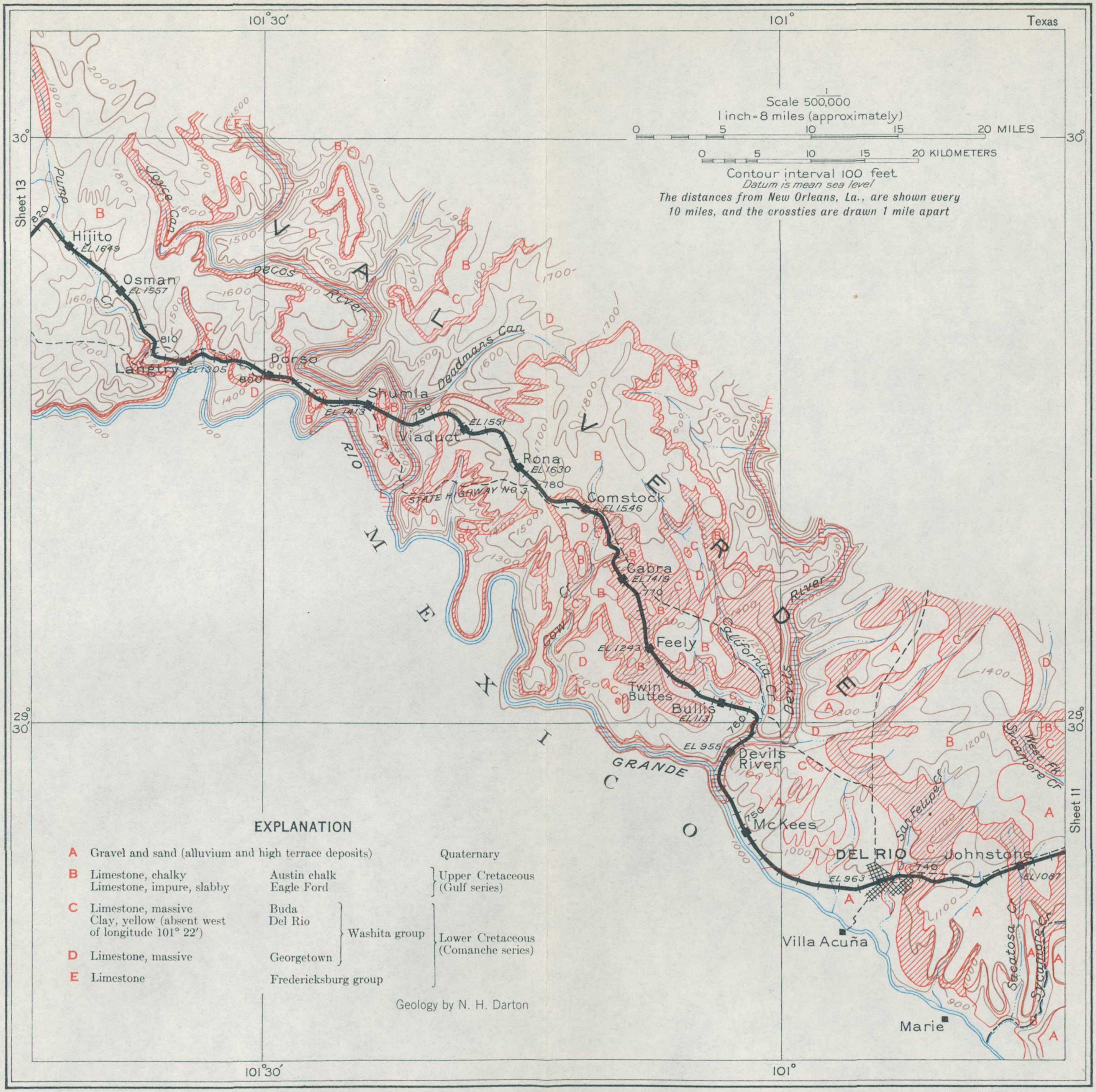
With the coming of the white man, buffalo killing became an organized business. A man was paid 25 cents for skinning an animal, and could handle 25 to 40 hides a day. In 1877–78 more than 100,000 animals are said to have been slaughtered for hide or for meat. Buffalo hides, which at first brought several dollars each, finally became so cheap as to be hardly worth taking. Many bulls were killed only for their tongues, which were a great delicacy. The ruthless slaughter finally resulted in the extinction of the herds, which formerly were so vast that they stopped immigrant trains. Then the gathering of the bleached bones that covered the prairies became an industry. From $6 to $12 a ton was paid for them, and more than 500,000 tons were handled by the two railroads. Great piles of bones stacked awaiting shipment became a frequent sight.

West of the Pecos Canyon is a rocky plateau of Georgetown limestone which in places to the west is capped by Buda and Eagle Ford limestones. The relations of these three formations are well shown in the railroad cut a mile east of Shumla siding. The Del Rio clay is generally absent in this vicinity and for 40 miles west; the last exposure (in which it is only 3 to 6 feet thick) is near the highway south of the Pecos bridge. The Buda limestone, 15 to 20 feet thick, a white massive rock breaking into irregular fragments, is exposed at many places. Near Dorso siding the overlying Eagle Ford limestones appear again, and there are several cuts in which they are well displayed. Their slabby bedding and pale-reddish tint are very characteristic. West of Dorso they occupy a shallow basin in which a thickness of about 200 feet remains, the higher beds making prominent buttes and ridges. In approaching Langtry a downgrade brings the railroad onto Buda limestone, which walls several small canyons, and finally the massive underlying Georgetown limestone is revealed in several small but steep-walled canyons crossed by the railroad. This formation makes 50-foot bluffs on the banks of the Rio Grande at Langtry and extending up and down the valley for some distance. The Eagle Ford beds are well exposed in the higher lands adjoining the railroad in this vicinity, and they also constitute high hills in Mexico. At many places in this general area the Buda limestone is exposed in railroad and stream cuts, lying directly on the smooth surface of the massive upper member of the Georgetown limestone. Its chalky-white appearance is characteristic.

Langtry.
Elevation 1,305 feet.
Population 165.*
New Orleans 807 miles.

Langtry is a small trading and shipping station built on a rocky shelf of Georgetown limestone on the north bank of the Rio Grande. In the slopes above and along the railroad are excellent exposures of Buda limestone capped by Eagle Ford beds. A short distance west are large springs from which the water is pumped for railroad use.

Langtry is famous in Texas history as the headquarters of the famous "Judge" Roy Bean during the days when no legitimate



Topography from sheets 403 and 423, Progressive Military Map, Corps of Engineers, U. S. Army

WILLIAMS & HEINTZ CO., WASH., D. C.

law courts existed in the region. A Kentuckian and a member of the Doniphan expedition of 1846 into Mexico, "Judge" Bean dispensed liquor and supplies and acted as the embodiment of "the law west of the Pecos" for many years in a shack which was falling to ruins in 1932. He changed the name from Vinegarone to Langtry in honor of the English actress Lily Langtry and had high expectations that she would visit the place. Some years later, on her way east, she stopped over a few hours to inspect her namesake, but meanwhile the autocratic old judge had died. The town saw considerable activity a few years ago when it was headquarters for the rebuilding of the railroad for several miles west and east to eliminate some curves and heavy grades. These changes shortened the line considerably, and the next milepost beyond 451 is 456 (from Harrisburg, Tex., an official terminus of one of the Texas railroad corporations now included in the Southern Pacific system). The resulting cuts, especially those west of Langtry, some of which are 40 feet deep, give very fine exposures of the Eagle Ford buff slabby limestone at frequent intervals nearly to Pumpville. Near that place the route traverses higher beds of chalky limestone (basal Austin) constituting a rolling plain of considerable extent. (Turn to sheet 13.)

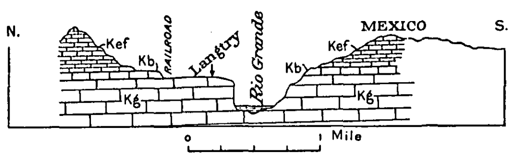


FIGURE 8.—Section at Langtry, Tex. Kef, Eagle Ford limestone; Kb, Buda limestone; Kg, Georgetown limestone (all Cretaceous)

Pumpville siding, a section house and pump station, is on the summit of the divide east of Lozier Creek. Wells here supply excellent water for locomotives; this water is also used for irrigation about the station with conspicuous results. The rapid descent west from Pumpville reveals Eagle Ford buff slabby limestones and then the Buda limestone, all lying nearly horizontal. Lozier Canyon, reached just beyond Lozier siding, is a large arroyo, usually dry but in times of freshet carrying a large stream. In the canyon slopes near Lozier and past Malvado siding are many fine exposures of the Eagle Ford-Buda contact, showing conformity of attitude, with low dips to the south and east. Below the Buda, which is conspicuous as a light-colored massive limestone, are low cliffs of the massive dark-gray top member of the Georgetown limestone. The Buda limestone is in two members of slightly different aspect and texture, and the yellow Del Rio clay that underlies it to the east is entirely absent, although near the large iron bridge over Meyers Canyon 2 feet of the basal limestone of the Buda carries *Exogyra arietina*, a fossil characteristic of the Del Rio clay. The Georgetown limestone is exposed in the bed of the wash from Meyers Canyon to a point below Lozier. As the railroad ascends the valley of Lozier Creek past Malvado, Watkins,

Pumpville.
Elevation 1,817 feet.
Population 30.*
New Orleans 822 miles.

and Thurston sidings the chalky-white massive lower member of the Buda limestone is conspicuous in places overlain by Eagle Ford beds. On the low plateau to the north is a mantle of gravel and sand which was deposited by an earlier Lozier Creek at a higher level, a stream which had its source in the highlands far to the west. Remnants of this deposit occur south of Dryden, about Mofeta, and in the region south of Maxon Creek, 20 miles southwest of Sanderson. It contains chert, sandstone with Pennsylvanian fossils, and novaculite, from the Marathon uplift, and lavas from the Davis Mountains.

About 5 miles west of Thurston siding an increase in dip brings up the basal member of the Buda limestone and reveals the underlying Del Rio rusty buff clay, which has come in again underground and extends to and beyond Dryden.

Dryden.
Elevation 2,108 feet.
Population 60.*
New Orleans 854 miles.

At Dryden State Highway 3, which crosses the highlands to the south, comes to the railroad and continues westward for some distance along its south side. Dryden is in a broad, shallow valley bordered by low ridges of Buda limestone underlain by Del Rio clay of rusty buff color. The Buda consists of two massive limestone members separated by softer yellowish marly beds which contain distinctive fossils. A mile or so west of Dryden these strata are covered by the old river deposit above referred to, which constitutes a wide, level plain. On the west side of this plain, about 2 miles west of Mofeta siding, the Georgetown limestone comes to the surface. To the south are high mountains in Mexico, which appear to be not very distant. A short distance beyond Mofeta the railroad descends into the canyon of Sanderson Creek, which it then ascends to its head, 40 miles to the west. The picturesque canyon walls are about 200 feet high and consist of Edwards and Comanche Peak limestones at the base and Georgetown beds above, the latter mostly massive limestone but in places including some thin members of a more marly nature in which Washita fossils are found. In this area the beds rise to the west on the beginning of a large dome-shaped uplift which culminates in the Marathon Basin and Glass Mountains. Some years ago a deep boring for oil was made on the east slope of this dome at a point about 12 miles southeast of Sanderson. It penetrated all the Lower Cretaceous strata, 840 feet thick, and more than 1,000 feet of the underlying black shales of Pennsylvanian age, but obtained no petroleum. Another deep hole near Emerson, 10 miles west, had a similar result.

Sanderson.
Elevation 2,775 feet.
Population 1,254.
New Orleans 875 miles.

Sanderson is the first town of any size west of Del Rio and is a local center of trade and a shipping point for stock. It lies on the flat-bottomed canyon of Sanderson Creek, which is bordered by cliffs consisting of a massive bed of Edwards limestone lying on slabby beds of Comanche Peak limestone and overlain by a succession of massive and softer beds representing the Georgetown limestone, about 200 feet in all. West of Sanderson the canyon is ascended on a moderate grade, and as the slope of the valley and the easterly dip of the beds are about the same in rate and direction the succession of strata is uniform for several miles past Gavilan and Emerson sidings. The adjoining highlands, capped by Georgetown limestone, are so deeply incised by side draws and canyons that but little of the original plateau surface remains. The rocky slopes support a scanty growth of desert plants, and there is more or less mesquite growing in the gravelly soil of the valley floor. Just west of Emerson siding is the deep boring referred to on page 84. In places west of Emerson a diminution of dip causes some of the lower beds of the limestone succession to pass beneath the bottom of the valley, and the limestone walls become less high and precipitous.

In the region southwest of Sanderson and south of Alpine the Rio Grande makes a great deflection to the south, and the country here embraced by the river is known as the Big Bend. It is a very thinly populated region of high mountains and many deep canyons, notably those which the river has cut through some of the plateaus and ridges. One of the most notable of these is the Santa Helena Canyon, near Terlingua, which has very high, precipitous walls of limestone of the Comanche series. In the earlier days the Big Bend country harbored many outlaws, and large numbers of cattle were smuggled across the Rio Grande at fords and other crossings. It was also a favorite region for the Indians, mainly the Apache Lipans. These people utilized the abundant maguey and sotol plants, baking the buds of the flower stalk in ovens of heated rocks and fermenting the juice into an alcoholic beverage of considerable potency. Long prior to these Indians there was an earlier race which left traces of their homes and numerous pictures on cliffs.

There are many remarkable plants in the Big Bend country and other parts of western Texas. Resurrection plants, or "flor de peña" (*Selaginella lepidophylla*), occur in large numbers on some of the rocky surfaces; many of them are sold as curiosities. When dry they roll into a nestlike ball, but when wet they unfold into a mass of fernlike fronds of a rich green color. The Mexicans use a decoction of this plant as a cure for colic and indigestion. One of the common weeds of the region, called trompillo (trome-pee'yo; *Solanum elaeagnifolium*), with violet flowers and a berry like a small black marble, is much used by the Mexicans for curdling milk in making cheese. Another rather notable plant is a small, low cactus, *Lophophora williamsi*, of radish shape, called peyote by the Mexicans and Indians. It bears a pale-pink flower in the early summer which develops into a greenish berry in a woolly sack, formerly much chewed by Indians, especially in ceremonial prayers for the sick; some alkaloid content has a mildly intoxicating effect, so that it has been called "white whisky." Many rocky slopes are dotted with a cactus resembling a huge pincushion (*Echinocereus stramineus*), which bears a delicious fruit, locally called pitahaya.

The plateau region extending west from Dryden to Longfellow and beyond appears rocky and barren, but it affords fairly good pasturage and sustains many cattle; sheep and goats are also raised with a large yield of wool and mohair. The old Texas longhorn cattle have been displaced, mostly by white-faced Herefords, which make more beef, are hardier, and withstand the arid climate. There are also many Brahmas, characterized by a hump and short straight horns; this stock was introduced from India and has proved to be well adapted to the dry climate. (See pl. 12, *B*.) The great "open range," however, is mostly a feature of the past, and now, although there are some very large pastures, all are inclosed by barbed-wire fences. The old "round-up" is no longer the great event in ranch life, and most of the branding is done at the home corral. (Turn to sheet 14.)

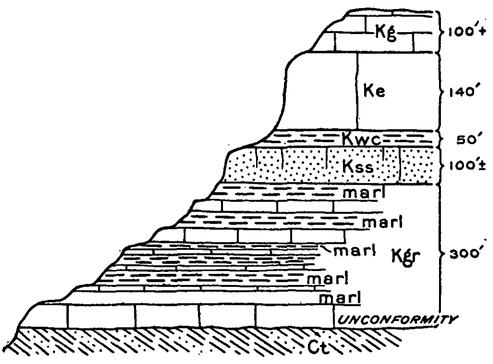


FIGURE 9.—Section near Maxon, Tex. Cretaceous: Kg, Georgetown limestone; Ke, Edwards limestone; Kwc, Walnut and Comanche Peak limestones; Kss, sandstone; Kgr, Glen Rose formation. Pennsylvanian: Ct, Tesnus formation

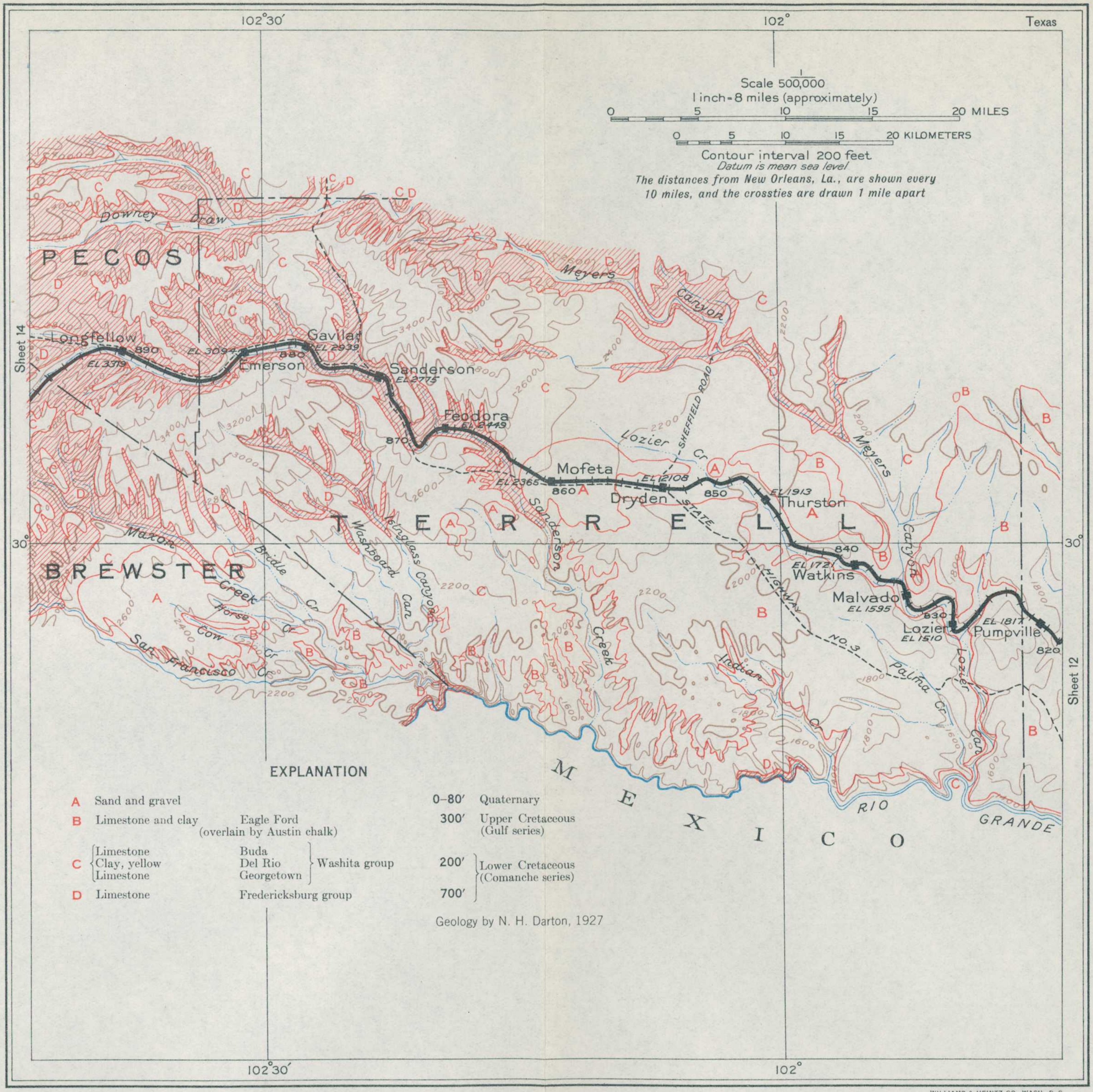
A few miles beyond Longfellow the tracks deflect to the south. Highway 3 continues west up the Dry Creek Valley to a divide somewhat higher than the one utilized by the railroad.

Longfellow.
Elevation 3,379 feet.
Population 30.*
New Orleans 891 miles.

The railroad follows a wide valley, which is drained in part by Sanderson Creek and beyond Rosenfeld siding by Maxon Creek. The walls of the valley consist of the Edwards and Georgetown limestones, which crop out in massive gray ledges.

Near Maxon siding a prominent ledge of brown sandstone 100 feet thick appears beneath the Edwards limestone in the canyon walls and is in turn underlain by impure limestones and shales of the Glen Rose formation of the Trinity group, which crop out in a succession of benches and slopes, as shown in Figure 9. The walls are 300 to 500 feet high near Maxon, but they are mostly broken into ridges and buttes. Maxon is near Maxon Springs, named for Lieutenant Maxon, of the United States Army, who first described it.

Three miles beyond Maxon the railroad swings to the west and, leaving the limestone canyon, enters a broad plain out of which rise many ridges of moderate height. This is the eastern edge of the Marathon Basin. A short distance east of Tesnus siding the railroad



Topography in part from maps by U. S. Army Corps of Engineers and by U. S. Geological Survey, and in part by N. H. Darton

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passes onto strata of Paleozoic age, which underlie the limestones and shales of the Trinity group. The Paleozoic rocks exposed near Tesnus siding are sandstones and shales of the Tesnus formation, of Pennsylvanian age, of which this is the type locality. It gives rise to rounded hills, on which are many russet-brown outcrops of the sandstones.

Tesnus.
Elevation 3,725 feet.
New Orleans 911 miles.

The Marathon Basin, which is entered near Tesnus, is an area of plains and low ridges about 40 miles wide, in which rocks of Paleozoic age are extensively exposed.[62] It is surrounded on all sides by escarpments of the limestones of Cretaceous age which formerly extended entirely across the region but have been removed by erosion from the area of the Marathon Basin. The basin occupies the truncated crest of the

[62] The following table and description of the Paleozoic formations exposed in the Marathon Basin are furnished by P. B. King:

Age	Formation	Thickness (feet)	Character
Pennsylvanian series.	Gaptank formation.	1,800	Limestone, interbedded with shale, sandstone, and conglomerate. Exposed only on north side of Marathon Basin, where it is overlain by the Permian.
	Haymond formation.	2,500	Thin-bedded sandstone and shale, with thick beds of arkose and boulder conglomerate in upper part near Haymond siding.
	Dimple limestone.	400–1,000	Limestone and interbedded shale, cropping out in low, narrow ridges.
	Tesnus formation.	7,500	Thick-bedded brown sandstone, with some interbedded shale, with a member of dark shale at the base several thousand feet thick.
Devonian (?) system.	Caballos novaculite.	200–600	Novaculite and chert, which crop out in prominent ridges.
Ordovician system.	Maravillas chert.	100–400	Black chert and limestone.
	Woods Hollow shale.	500	Drab shale, with interbedded flaggy brown sandstone and limestone.
	Fort Peña formation.	150	Massive limestone, bedded reddish chert, and some conglomerate.
	Alsate shale.	50	Shale and thin limestone beds.
	Marathon limestone.	500–800	Flaggy gray limestone, with a thin medial member of cherty dolomite; much shale and some conglomerate.
Cambrian system.	Dagger Flat sandstone.	300+	Shale with thin brown limestone and sandstone beds, passing down into massive sandstone.

The Cambrian and Ordovician rocks differ considerably from those in the region of Van Horn and El Paso, only a few hundred miles away, where the basal sandstone is overlain by several thousand feet of Ordovician and Silurian limestones. Near Marathon there is much sandstone, shale, and conglomerate in addition to limestone. The fossils are also different. The Ordovician rocks at Marathon contain chiefly graptolites and linguloid brachiopods, animals which lived in an environment of turbid water; the Ordovician strata at El Paso and Van Horn contain cephalopods, gastropods, and sponges, which lived in a clear sea where limy sediments were being

Marathon uplift, a great dome in the earth's crust, by which all the strata have been uplifted 4,500 feet or more in an area about 100 miles in diameter. The east side of this dome is crossed between Longfellow and Tesnus, where the canyon walls expose successively lower parts of the Comanche series and finally the underlying rocks of Paleozoic age. This is caused by the westward rise of the strata toward the crest of the Marathon dome.

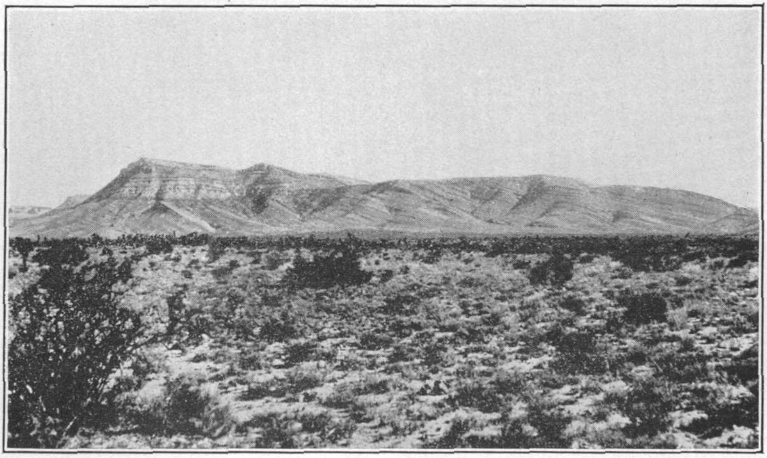
Near Tesnus the strata of the Comanche series are cut off by erosion and present high, westward-facing escarpments which rise far above and afford fine views of the Marathon Basin lying below them to the west. In places, also, they constitute more or less isolated outlying buttes and mesas, west of the main escarpment. The most prominent part of the escarpment near the railroad is House Mountain, which lies north of the tracks a few miles west of Tesnus. This broad cuesta (elevation 5,460 feet) has a steep face on the west and rises 1,500 feet above the plains at its base. [63]

deposited. These differences are due to differences in local conditions, and it is probable that the sediments in the Marathon region were deposited closer to an old shore line than those in the El Paso and Van Horn regions.

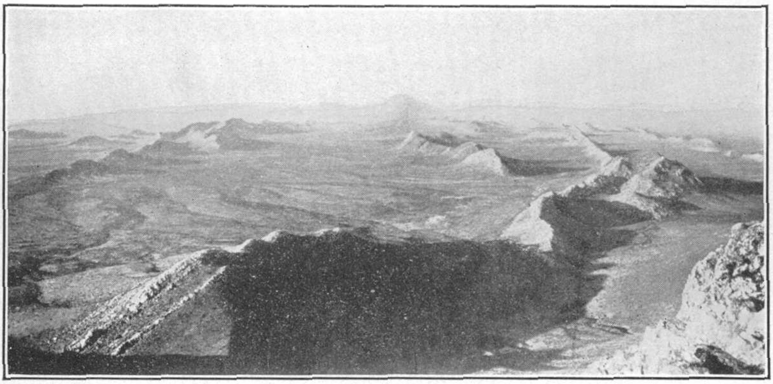
The Pennsylvanian rocks also give evidence of a shore line near the Marathon region in Paleozoic time. They are very thick and consist almost entirely of shale and sandstone, with some beds of conglomerate. Marine fossils are not very abundant, except in the highest formation, and the lower formations are characterized chiefly by the remains of land plants. It is probable that the sand and clay of the Pennsylvanian were washed down from high lands to the southeast and were deposited in a series of deltas along the shore line. The three older Pennsylvanian formations are regarded as of Pottsville age, and the fossil shells in the upper formation are like those of the well-known upper Pennsylvanian (post-Pottsville) strata of Kansas and central Texas.

[63] The upper part of House Mountain consists of Comanche limestone dipping gently to the east, and the lower slopes consist of russet-brown sandstone and shale of the Tesnus formation (Pennsylvanian), which dips about 45° SE. The strata of the two series thus present a great angular unconformity, which is clearly revealed on the escarpment as shown in Plate 13, *A*. Some of the relations here and farther west are shown in Figure 10. The mass of older rocks is beveled to a nearly perfect plain on which the Comanche strata lie.

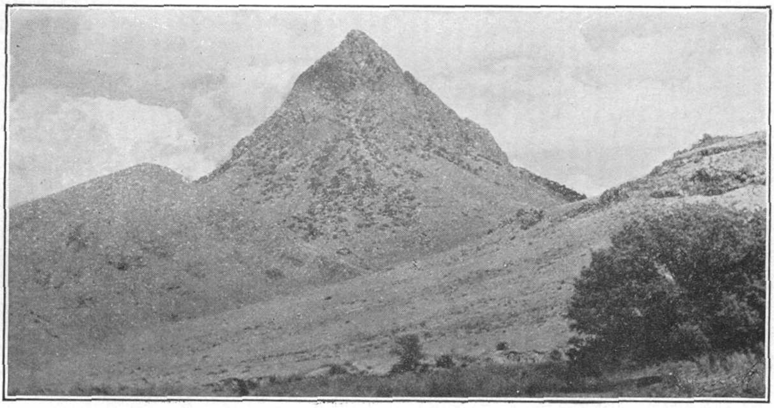
The Paleozoic rocks in the vicinity of House Mountain acquired their steep inclination as a result of folding during the later part of the Paleozoic era, which involved the entire area of Paleozoic rocks in the Marathon Basin and probably far beyond. The folds have a northeastward trend. At the time of the folding there was faulting in places. Some of the faults dip at low angles to the southeast and are planes along which blocks of the Paleozoic rocks have been displaced for many miles to the northwest. The folds in these Paleozoic rocks are like those in the Ouachita and Appalachian Mountains and were formed at about the same time. After Paleozoic time the folded rocks of the Marathon Basin were beveled by running streams and the general processes of weathering, and in later Mesozoic time the Lower Cretaceous sediments were deposited on their upturned edges. The deformation of the Cretaceous sediments and the development of the Marathon uplift occurred long afterward.



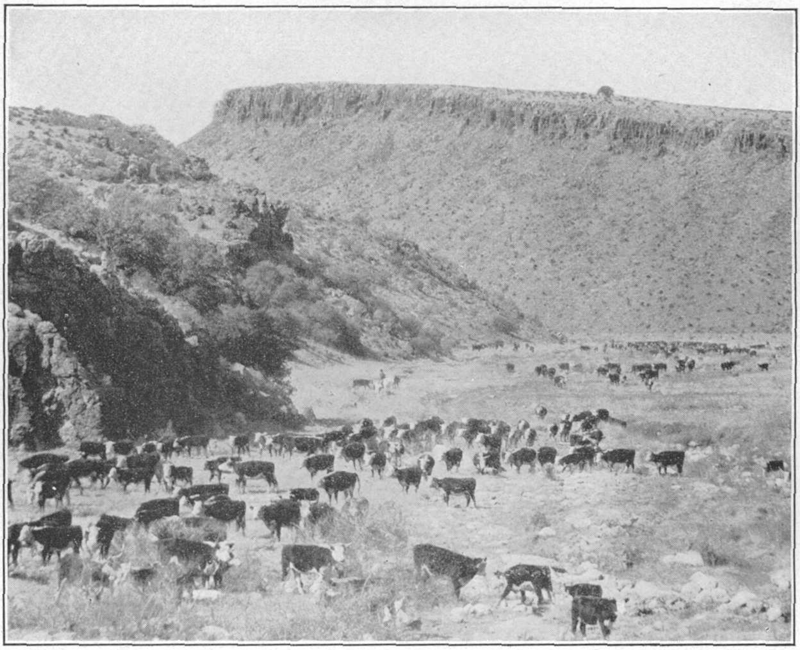
A. CONTACT OF OVERLAP OF COMANCHE LIMESTONE ON TILTED STRATA OF PENNSYLVANIAN AGE NORTHWEST OF TESNUS, TEX.
(P. B. King.)



B. SINUOUS RIDGES OF HARD BEDS IN MARATHON BASIN
(P. B. King.)

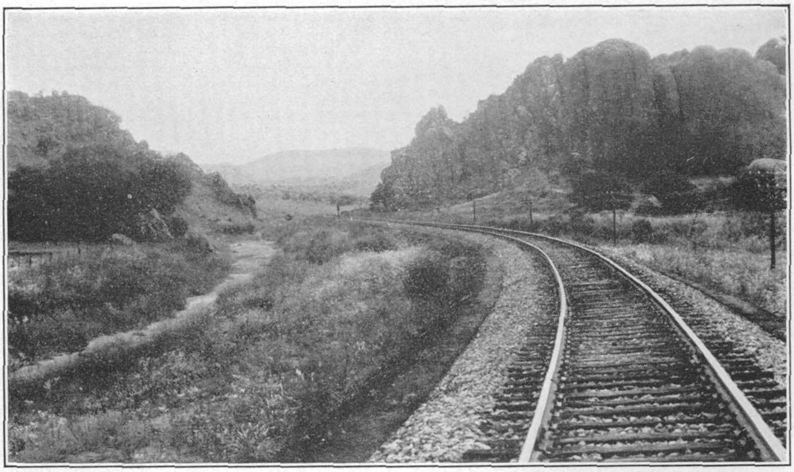


C. MITRE PEAK, 6 MILES NORTHWEST OF ALPINE, TEX.
A mass of igneous rock, probably an outlet for lavas in the surrounding region.



A. LAVA AND TUFF OF DAVIS MOUNTAINS, WEST OF ALPINE, TEX.

Typical herd of Hereford cattle in foreground.



B. APPROACHING PAISANO PASS THROUGH DAVIS MOUNTAINS, BETWEEN ALPINE AND MARFA, TEX.

Looking east.

Another outstanding promontory lies south of Tesnus and comes into view a short distance beyond Maxon. Merging into the plateau near Maxon at an elevation of 3,700 feet, in 6 miles it rises considerably higher to its western termination, where it breaks into three peaks known as Tres Hermanas, each capped by a small mass of Edwards limestone. The ridge stands 1,300 feet above the plains to the north, but its steep southern front rises 2,000 feet above the valley of San Francisco Creek.

The sharp ridges of the basin, underlain by hard rocks, extend across it in a northeastward direction. Some of them run nearly straight for many miles; others have a winding course, as shown in Plate 13, *B*, expressing the complex deformation of the strata. On many of the ridges are ledges of white siliceous rock called novaculite. Between the ridges are wide valleys covered by soil and gravel, but along the larger drainage ways the land is cut by many arroyos into a maze of terraces and shallow, steep-walled valleys. Much of the

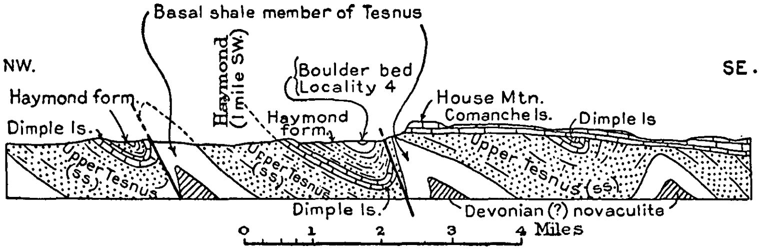


FIGURE 10.—Section through House Mountain, about 1 mile north of the railroad northwest of Tesnus, Tex.

terrace gravel consists of white novaculite and has the appearance of drifted snow.

West of Tesnus Horse Mountain is prominently in view 10 miles to the southwest. This is the highest peak in the Marathon Basin (elevation 5,010 feet) and is a dome-shaped mass of novaculite of anticlinal structure. The railroad crosses a level plain for several miles west of Tesnus and then descends into a region of hills and valleys, drained by San Francisco Creek.[64]

Within the Marathon Basin the Paleozoic rocks constitute low, sharp ridges far inferior in magnitude to the mountains that must have existed when the folding of later Paleozoic time took place. The present low ridges were produced by erosion in post-Cretaceous time, after the Marathon dome was uplifted and the Cretaceous rocks were eroded from the area of the Marathon Basin.

[64] A few miles beyond Tesnus the railroad crosses a fault, not visible from the tracks but well exposed some miles to the north and south, which brings the Tesnus strata against the higher part of the Haymond formation occupying a syncline. The highest exposed member of this formation, also concealed by gravel near the railroad but well exposed in slopes not far away, is a remarkable conglomerate containing

Beyond the edge of the gravel plain 5 miles west of Tesnus thin-bedded sandstone and shale of the Haymond formation are exposed in some of the railroad cuts, and the massive arkose, which directly underlies the boulder bed, crops out in conspicuous ledges along the edge of the valley not far to the south. After crossing the Haymond beds the railroad follows the gap cut by San Francisco Creek across the sharp, narrow ridge of steeply tilted Dimple limestone, a ridge typical of the outcrops of this formation throughout the Marathon Basin, and continues down the valley past Haymond, which is on an anticlinal area of Tesnus sandstone, some ledges of which are well exposed along the railroad and creek.

Haymond.
Elevation 3,883 feet.
New Orleans 919 miles.

Haymond siding, which lies in the valley of San Francisco Creek, is now a very small place but was at one time a town of considerable size. It was the railroad station for Fort Stockton, 60 miles to the north, when that was an important frontier fort. The rocky hills near Haymond are underlain by various formations of Pennsylvanian age. To the east and west of it are low ridges of the Dimple limestone, between which are lower lands underlain by sandstones and shales of the Tesnus and Haymond formations. These rocks are folded into several sharp anticlines and synclines.

Northwest of the ridges of Dimple limestone the railroad again enters a much gullied plain of terrace gravel, underlain by sandstones and shales of the Tesnus formation. The Caballos novaculite (Devonian?), which lies beneath the Tesnus, crops out to the northwest, about 3 miles beyond Haymond, in low ledges and ridges. This novaculite is a white siliceous rock, probably a variety of chert, in more or less massive-bedded layers. The name was applied to closely similar "whetstone rock" in Arkansas by Schoolcraft in 1819. Novaculite is of rare occurrence in this country, in comparison to such other sedimentary rocks as sandstone, shale, and limestone. The novacu-

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rounded and angular masses of rocks of many kinds, most of which do not crop out in the Marathon area. The fragments are rather widely set in a matrix of arkosic mud and consist of cobbles of pre-Cambrian gneiss, granite, schist, aplite, and pegmatite, large angular blocks of Upper Ordovician limestone, Devonian chert and novaculite, Tesnus quartzite, Dimple limestone, gray limestone with fossils of middle Pennsylvanian age, and siliceous breccia, probably a fault breccia. Blocks 5 to 15 feet across are common, and one block of Dimple limestone south of the railroad is over 100 feet long. The large masses, however, are most abundant a mile or more north of the railroad.

The various pre-Cambrian to Carboniferous ingredients in this conglomerate indicate that there was a near-by area of upturned older strata in upper Haymond time. Probably it was situated south of the present uplift and is now deeply buried beneath younger strata. It is difficult to understand how the coarse materials were transported to their present position, for the larger masses could not have been carried by ordinary streams; they may have been overthrust—a condition that might account for the presence of the blocks of fault breccia.

lite that crops out in ridges northwest of Haymond, here about 300 feet thick, lies on the northeast end of a great anticlinorium (an anticlinal arch with subordinate flexures) which brings pre-Pennsylvanian rocks to the surface over a wide area in the central part of the Marathon Basin. The strata of the anticlinorium are folded into several sharp anticlines and synclines and are broken by overthrust faults. Owing to its great hardness the novaculite is a ridge maker, and its white outcrops are very conspicuous.

Between the north end of these novaculite hills and Marathon the railroad crosses a flat gravel-covered plain. To the south are low hills of the novaculite, and to the north less conspicuous hills of Dimple limestone.

Marathon.
Elevation 4,045 feet.
Population 826.
New Orleans 935 miles.

Marathon is a village of considerable importance, named for a general of the United States Army who established a road from Fort Stockton to Presidio in 1854. It is a local center for large cattle interests and is the shipping point for the quicksilver produced at the mines of Terlingua, 70 miles to the southwest. These mines have been an important source of mercury since 1894 and produce 2,500 to 3,000 flasks (of 76 pounds) a year (Bureau of Mines). At one time a rubber factory was operated successfully at Marathon, making use of the guayule plant (*Parthenium argentatum*) as long as the local supply was available. Resin from the candillia plant has also been shipped from Marathon for use in making phonograph disks.

The village of Marathon is built on ledges of flaggy limestone and massive conglomerate of the Marathon limestone (Ordovician). This is the only pre-Devonian formation well exposed near the railroad, but in low hills not far south of Marathon there are extensive outcrops of strata from Cambrian to Devonian in age. West of Marathon low rugged ridges of Caballos novaculite may be seen to the south and behind them a high conical mountain of intrusive syenite, Santiago Peak, 25 miles distant (elevation 6,521 feet). To the west are the eastward-facing escarpments of the Del Norte Mountains, made up of limestones of the Comanche series, which form the western rim of the Marathon Basin.

Near Marathon and to the west the Glass Mountains are conspicuous to the north. The name is a translation of the Spanish Sierra del Vidrio, said to have been given because of the glassy appearance of the limestone cliffs when seen from a distance. According to Hill,[65] however, the name Glass Mountains was first used for the novaculite ridges of the Marathon Basin and was later transferred

[65] R. T. Hill, a pioneer in the geologic exploration of Texas, established the classification of the Cretaceous rocks in that State and mapped them over a wide area. His work on the physiography of Texas gave the first clear conception of the relations of the Edwards Plateau and of many other important topographic features of the State.

through error to the mountains to the north, which had before been known as the Sierra Comanche. The Glass Mountains form the northern and northwestern rim of the Marathon Basin and have the form of a cuesta or sloping mesa which trends northeast. The southward-facing escarpments of these mountains rise 1,000 to 2,500 feet above the general level of the Marathon Basin and in the western part present a high broken crest of bold cliffs of dolomite, which attain an elevation of 6,500 feet.

The Glass Mountains are carved from Permian dolomites, limestones, and shales, tilted northwest. These beds are overlain unconformably by the Lower Cretaceous strata and lie unconformably on the Pennsylvanian strata.[66]

Six miles southwest of Marathon is old Fort Peña Colorada, which was located near a gap in a novaculite ridge, where there is a spring and one of the few streams of running water in the region. This was a station on both the military road east and west and the Comanche trail that led southward from Fort Stockton to the Rio Grande. At one time it was garrisoned with soldiers to protect travelers from Indians and outlaws.

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[66] The following table, by P. B. King, shows the Permian formations of the Glass Mountains:

Formation	Thickness (feet)	Character
Bissett conglomerate.	700	Conglomerate of limestone fragments, with some red beds and limestone.
Capitan limestone.	3,000	Massive dolomitic limestone, probably of reef origin, which grades eastward in part into thin-bedded limestone and westward in part into sandy limestone.
Word formation.	1,200	Sandstone and siliceous shale, with thick beds of limestone. Changes eastward into cherty limestone.
Leonard and Hess formations.	2,000	Sandstone and siliceous shale (Leonard), which change eastward into thin-bedded limestone (Hess). Basal conglomerate.
Wolfcamp formation.	700	Shale and limestone; rests on strata of Pennsylvanian age, locally with great unconformity.

These formations show complex changes in lithologic character along the strike of the mountains. In the eastern half of the range nearly all the strata are limestone; in the western half there are also thick beds of sandstone and shale. These changes in lithology are shown in Figure 11. With the exception of the Bissett conglomerate, the Permian rocks of the Glass Mountains are all of marine origin. They contain a great variety of marine invertebrate fossils comprising foraminifers, sponges, corals, crinoids, ammonoids, gastropods, pelecypods, bryozoans, and a great number of brachiopods in which the *Productus* group greatly predominate. The brachiopods include several aberrant types, such as *Leptodus* and *Richthofenia*. A feature of the fossils in the Glass Mountains is their almost universal preservation by silicification. This replacement of the original shell material has proceeded in a most delicate manner, so that fine external ornaments and

About midway along the south edge of the Glass Mountains is the bald reddish knob of Iron Mountain, a stock of intrusive syenite which cuts across the Permian strata.

Four miles west of Marathon the railroad crosses low ledges of the Gaptank formation, which contains marine fossils of upper Pennsylvanian age. Several railroad cuts expose steeply dipping shale, sandstone, and conglomeratic limestone. About a mile to the south of the tracks are several low hills of novaculite and chert. In other novaculite hills, visible farther southwest, the novaculite has been overthrust onto the Gaptank formation by a fault, with the older strata in nearly flat contact. This displacement, called the Dugout Creek overthrust, had a horizontal movement of nearly 6 miles in a northwestward direction. Some of its relations are shown in Figure 12. North of the novaculite hills above mentioned and west of Lenox siding, the basal Permian beds are exposed in Dugout Mountain, resting on the steeply inclined and contorted Pennsylvanian rocks; as the Permian beds contain coarse conglomerates derived from the erosion of older rocks, the Dugout Creek overthrust is pre-Permian and probably later Pennsylvanian.

Near Lenox siding the railroad passes between low hills of the lower Permian rocks, of which Dugout Mountain is one, and leaves the Marathon Basin. The high escarpment of the Glass Mountains comes into view to the northeast, behind lower foothills. The slopes of the escarpment are shale and sandstone of the Word formation, which are surmounted by cliffs of Capitan limestone. The most imposing exposure is on Cathedral Mountain, several miles northeast of the railroad. The limestone of the cliffs was probably built up in reefs on the Permian sea floor by calcareous algae and other organisms. These beds thin to the west, and on the scarp near the railroad near Altuda they are of negligible thickness.

Altuda.
Elevation 4,642 feet.
New Orleans 951 miles.

Altuda siding is in the pass or low, wide gap between the north end of the Del Norte Mountains and the southwestern extension of the Glass Mountains. For several miles in this vicinity there are excellent views of both ranges, which are very rugged and bare. Altuda Mountain, to the west, and Mount Ord (named for General Ord, one time commandant of the military forces in Texas), to the south, are

spines and minute internal structures are preserved. These are revealed by solution of the inclosing limestone by acid, which leaves the fossils in excellent condition. Eroded surfaces of these limestones are usually a tangled silicified mat of shells which accumulated on the sea bottom in Permian time. The faunas of the Glass Mountains are of the type known as the Guadalupian, which in North America is almost wholly confined to the west Texas Permian but in Europe and Asia is found in the typical Permian area. In the higher parts of the Glass Mountains section most of the limestones appear to have been built up of reef-making algae.

especially conspicuous. Altuda Mountain is capped by Capitan limestone, which forms a prominent cliff on its upper slope. At one point, as shown in Figure 13, there is an outlying mass of Comanche limestone. South of Altuda Mountain the Word and Leonard formations are tilted steeply northward away from an intrusive mass of syenite, which forms a dark-colored knob west of Altuda siding. On the northwestern or back slope of the Glass Mountains, in view north of Altuda, remnants of Comanche limestone may be seen, resting on the Capitan limestone.

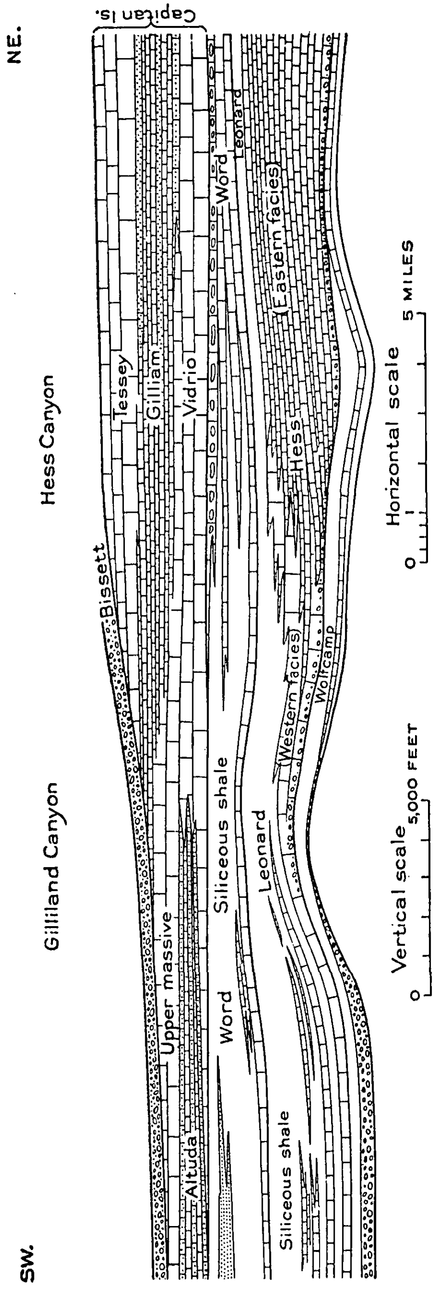


FIGURE 11.—Diagrammatic section showing lithologic variations in the Permian in the Glass Mountains, Tex. By P. B. King

At Altuda the railroad runs nearly north to pass around the north end of the Del Norte Mountains and in the main is in a wide valley floored with alluvial wash from the adjoining mountain slopes. From this plain rise several knolls of the underlying rocks, which indicate faulted structure, though the details are hidden by sand and gravel. Near Strobel siding the north end of the Del Norte Mountains is passed and the structural relations are well exposed. Here heavy ledges of Edwards and Georgetown limestones, dipping west and cut by two faults, pass beneath Upper Cretaceous rocks, and these in turn under the great volcanic succession (Tertiary) which extends far west in the Davis Mountain region. In the valley just south of Strobel are ledges of chalky limestone of Upper Cretaceous age which pass under the lower sheet of the lava succession. Beyond Strobel, as the railroad ascends and passes around the curve, there are very fine views of the rugged peaks of the volcanic region, notably of Mitre Peak, (see pl. 13, *C*), which lies several miles northwest. There is a downgrade into Alpine over volcanic rocks of various kinds.[67]

Alpine.
Elevation 4,884 feet.
Population 3,495.
New Orleans 966 miles.

Alpine is in the broad valley or amphitheater of Alpine and Leoncito Creeks, about 4 miles wide, with alluvial floor, flanked on all sides by cliffs and peaks of volcanic rocks of the Tertiary succession. It is an exceptionally beautiful location, and the views in all directions are very attractive. Originally called Murphysville, Alpine came into existence with the railroad, Texas rangers being established there to protect the builders from the Indians, who hotly re-

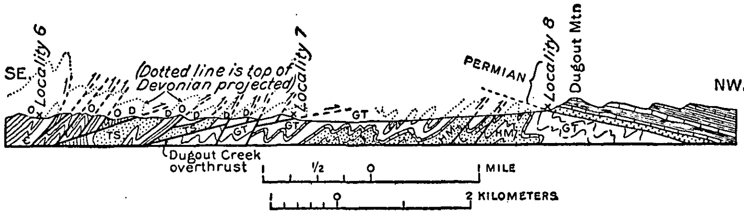


FIGURE 12.—Section southeast of Dugout Mountain, Tex., showing relations of the Dugout Creek overthrust. By P. B. King. Є, Cambrian; O, Ordovician; D, Devonian; TS, Tesnus formation; HM, Haymond formation; GT, Gaptank formation

sented their presence. It is now an important commercial center for the Big Bend and a wide area of stock country to the north and west.

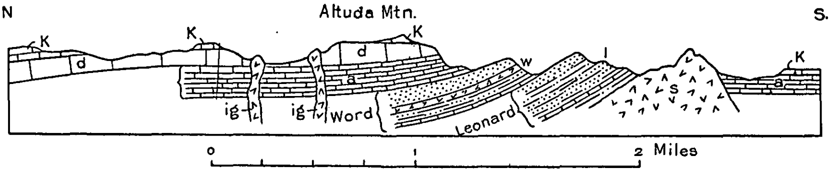


FIGURE 13.—Section of Altuda Mountain, northwest of Altuda siding, Tex. By P. B. King. a, Altuda limestone; d, massive dolomite (Capitan); K, limestone of Comanche age; l, Leonard formation; w, Word formation; ig, intrusive dikes; s, syenite mass

The Sul Ross Teachers College, established in 1920, is built on the side of a hill east of the town. This hill is composed of lava (trachyte) of

[67] In western Texas the later formations of the Upper Cretaceous are largely sandstones which carry local coal beds and contain bones of land animals. Much volcanic ash and tuff erupted from near-by volcanoes is intermixed and interbedded in places. These strata are overlain by a great succession of lava flows, tuff, and agglomerate of volcanic origin, most of which is regarded as of Tertiary age. Sedimentary beds in this succession contain leaves of Eocene age (Berry), and bones of Miocene animals occur in higher beds (Baker). In eastern Texas marine conditions persisted long into the Tertiary period, but western Texas from late Cretaceous time was an upland with local basins of deposition and many volcanic vents, from which there were vast eruptions of lava and fragmental material. Prior to these eruptions the Cretaceous strata were flexed and faulted, and in areas of most pronounced uplift there was considerable erosion, for locally the volcanic rocks lie on deeply eroded surfaces of the deformed strata. These volcanic rocks present the record of various episodes of igneous activity continuing

Tertiary age, but on its west slope 1¼ miles northeast of the station there is a small exposure of limestone of Comanche age dipping west, with relations shown in Figure 14. Near by, at the foot of the hill, is Kokernot Spring, or Charco de Alsate, on the Chihuahua trail from Fort Stockton to Presidio and the military road from Peña Colorada to Fort Davis. It was at this spring in the early days that a caravan of 40 freight wagons was surrounded by Apache Indians with the expectation that it would be easy prey. Fortunately one man was able to slip away and reach the United States Army post at Presidio, 100 miles distant, whence forces were sent to the rescue.

A water hole which the railroad crosses on a bridge just west of Alpine is thought to be the place where Juan de Mendoza camped on

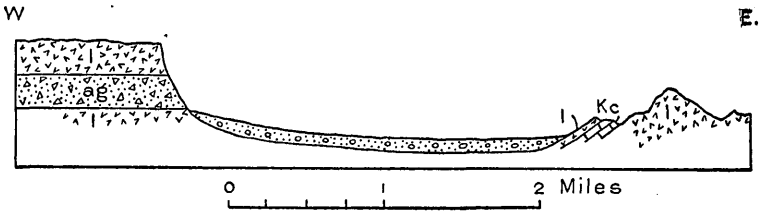
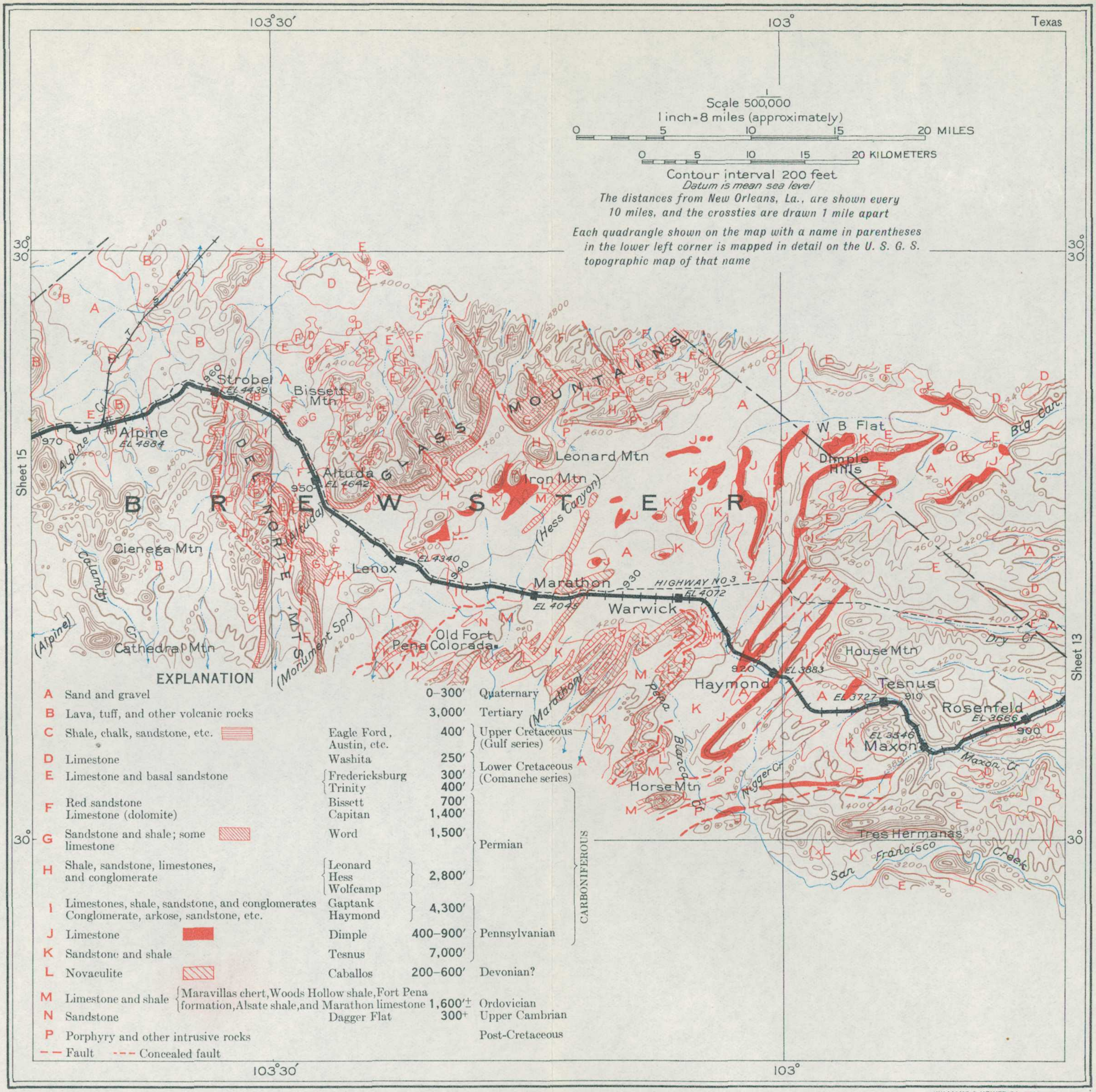


FIGURE 14.—Section across the Alpine Basin just north of Alpine, Tex. l, Lava (Tertiary); ag, agglomerate; Kc, limestone (Comanche)

January 4, 1684, on his notable exploration from the vicinity of El Paso across western Texas to Rio Concho. He was sent by Governor

well into Tertiary time. They came from far below the surface through cracks and craters in the older sedimentary rocks and spread widely as lavas, varying considerably in composition, extent, and sequence. Apparently the largest eruptions were in early or middle Tertiary time. A vast amount of fragmental material was also thrown out of the numerous vents. This consists of agglomerate or breccia (made up mostly of coarse fragments of lava) and tuff (finer-grained ash and cinders), and there was also some fine-grained volcanic ash. Most of this ejected matter piled up in sheets as it fell, but in some places water had a part in its distribution, and from some of the vents there also came extensive mud flows. At intervals and from place to place there were great outflows of lavas of various kinds that extended far over the surface of the deposits of fragmental material and were in places buried beneath later eruptions of breccia, tuff, and ash.

The lavas in this region are mostly of the varieties known as rhyolite and trachyte, with a small amount of basalt, but there is much local variation and great difference in the extent of individual flows. At the beginning of volcanic activity the configuration of the region was probably much smoother than it is now, for the old surface on which the volcanic deposits lie appears to be smooth at most localities. Several ridges of older rocks protruded, however, some of which were not covered by volcanic materials. After the main period of volcanic action in Tertiary time the region was uplifted and the sheets of lava and associated deposits were flexed, tilted, and broken. It is from the erosion of this irregular surface by streams and other agencies that most of the present land forms are derived. In places, especially where there has been great uplift, the volcanic rocks have been removed, laying bare the underlying older rocks.



Topography from U. S. Geological Survey quadrangle maps; east of longitude 103° by N. H. Darton

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Cruzate, of the province of Nuevo Méjico, to explore the kingdom of the Tejas Indians. According to his very clear journal, he came there from Antelope Spring, south of Marfa, and on leaving it followed Leoncito Draw to Comanche Spring (now Fort Stockton) and the Concho River at the present San Angelo. (Turn to sheet 15.)

The famous short-cut "smugglers' trail," which came from the Rio Grande, passed around the foot of Mount Ranger (now called Twin Peak), just west of Alpine and down Alpine Creek. The Davis Mountains, west and north of Alpine, were a great resort for the Indians, so that in 1854 Fort Davis (named for Jefferson Davis) was established at a point 20 miles northwest of Alpine. At this post food supplies and forage for horses were obtained with difficulty, so Mexican cattle were smuggled in from the great haciendas in Mexico to supply the troops at Fort Davis and Fort Stockton. In 1855 Secretary of War Jefferson Davis had camels introduced into this region as a means of transportation, but as they did not prove satisfactory to frontiersmen accustomed to horses and mules, they were turned loose and finally died in the Big Bend country. In 1854 the Government let a contract for monthly mail service between San Antonio and Santa Fe by way of El Paso in two-horse coaches, through in 25 days. The compensation was set at $16,750, but Indian depredations led Congress to increase this to $33,500. In 1857 another contract was signed for fortnightly mail between San Antonio and San Diego for $149,800. Two years later this line was costing the Government nearly $200,000 a year, with receipts of $601. The trip was about 1,500 miles long, consumed 22 to 26 days, and cost the traveler $200 with meals. Indians constantly attacked mail carriers and emigrants, the trail from San Antonio to El Paso being described as one long battleground. When the Civil War broke out Fort Davis was occupied by Confederates, but soon it was deserted and the entire Big Bend country was left to the Indians. After the Civil War Fort Davis was enlarged and reoccupied as an Army post until 1891. The region is now famous for its cool summer climate, fine fruit, and thoroughbred Hereford cattle.

It was intended to build the Southern Pacific Railroad through Fort Davis, but difficulty in obtaining a right of way led to its location farther south, through Paisano Gap.

Three miles west of Alpine the railroad enters a gorge in the volcanic rocks that constitute the Davis Mountains. These rocks are in a succession of thick sheets lying nearly horizontal or dipping at low angles (as shown in fig. 14 and pl. 14, *A*.) At the base, in this part of the area, is a massive bed of agglomerate, probably the result of a great mud flow during an eruption. It consists of huge fragments of lava, mostly angular, mixed with finer volcanic material. There are many irregular erosion forms, notably Mitre Peak, shown in

Plate 13, *C*. A large quarry for road ballast at Toronto siding shows a contact of two volcanic flows. South of the track, beyond Toronto, is the very high conical mass of Paisano Peak. It has a crater-form bowl in the top strongly suggestive of the remains of an old crater, and doubtless it was the vent of one or more of the great outbursts of lava that covered all the surrounding country.[68] Several dikes of dark-colored igneous rock crossed by the railroad west of this peak represent cracks up which lava welled to feed some of the later outflows. In this region numerous live oaks and a few junipers give a very pleasing effect to the landscape, and there is considerable grass, which sustains many cattle. A typical view on one of the large pastures in the mountains is given in Plate 14, *A*. The approach to Paisano Pass is shown in Plate 14, *B*.

In a pretty grove of live oaks a few miles beyond Toronto siding on the south side of the track is a Baptist camp-meeting ground, where each year large numbers gather from all quarters for a week of instruction and recreation. Another great camp-meeting ground, nondenominational and operated without charge to those attending, is at Skillman's grove, a few miles west of Fort Davis or north of Marfa, in a park among the volcanic peaks of the central part of the Davis Mountains. This grove was named for the man who first carried the monthly mail from San Antonio to El Paso and return.

Paisano.
Elevation 5,073 feet.
New Orleans 978 miles.

At Paisano siding,[69] in the divide on the Davis Mountains, the railroad reaches its highest elevation, near the western margin of the older volcanic lavas, which in this vicinity are mostly trachyte, as in the region about Alpine. Just west of the siding the railroad descends into a wide valley occupied by alluvium, doubtless underlain by volcanic rocks. A few rods beyond Paisano a line of the Atchison, Topeka & Santa Fe Railway system, which uses the Southern Pacific tracks from Alpine, here diverges to the south on the way to Presidio, on

[68] These rocks are all in extensive sheets which have been tilted, flexed, and faulted to some extent and considerably eroded. The materials are mostly soda trachyte, in places underlain by soda rhyolite and agglomerate. Soda rhyolite, conspicuous on Sunny Brook and at the foot of Twin Mountains west of Alpine, consists of phenocrysts of orthoclase in a groundmass of albite and quartz, as determined by C. S. Ross, of the United States Geological Survey.

[69] A dike near Paisano consists of a peculiar fine-grained dacite which has been named "paisanite" by Osann. Its components are mainly feldspar, hornblende, and quartz, with a tendency to granophyric structure. Apparently it was an outlet or feeder for one of the volcanic flows in the vicinity. Some distance south of Paisano is Cienega Mountain, which contains a mass of marble of good quality that has been quarried to some extent. It is limestone of Comanche age altered to marble by the heat of a large intrusive mass, which constitutes most of the mountain. This mass is a soda trachyte composed of sodic plagioclase and iron oxides similar to some of the great lava flows in the region about Alpine.

the Rio Grande, where it connects with a railroad to Chihuahua, Mexico. Tall yuccas, which become abundant in this area, extend far on the plains to the west. Near Marfa and westward nearly to Aragon siding lavas and tuffs are exposed along or near the railroad.

Marfa.
Elevation 4,692 feet.
Population 3,909.
New Orleans 992 miles.

Marfa is a small city of about the same size and character as Alpine, a local center for stock and other interests and the county seat of Presidio County since 1885. On the southern edge of the city is Fort D. A. Russell, where a regiment of 578 men and 37 officers is garrisoned. An important function of this station is military training for recruits. The Chihuahua Trail, which crossed the Rio Grande, at Presidio, came up Alamito Creek, passed through Antelope Spring, south of Marfa, followed Paisano Pass to Alpine, and went north to Fort Stockton, where it connected with other trails east. Over it ore from the mines of western Mexico was hauled in wooden-wheeled carts by Texas teamsters to San Antonio and thence taken to the coast to be shipped to Europe. One trader in five years transported in this way a million dollars' worth of freshly minted Mexican silver. It is still believed that silver and other valuable commodities were buried along this route to conceal them from outlaws or Indians.

West from Marfa the railroad follows a west-northwest course over a rolling country of lavas (basalt) and waterlaid tuffs. Low mesas to the south are capped by lava (basalt). Near Aragon siding the railroad passes over a low, wide divide leading into Ryan Flat, at the head of the broad valley of Chispa Creek. Far to the south may be seen the high Chinati Peak (che-nah'tee), which is due to an isolated intrusive mass. To the north are the Davis Mountains, consisting of high ridges and peaks of igneous rocks of the Tertiary volcanic succession. At Conejo siding (co-nay'ho) the railroad deflects somewhat into a 40-mile tangent extending nearly due northwest down the broad alluvial valley of Chispa Creek. The region has but little vegetation other than grass and is a prosperous stock country, mostly divided into ranches of large area.

Valentine.
Elevation 4,330 feet.
Population 314.
New Orleans 1,027 miles.

Valentine is a small village sustained mostly by stock raising on the large ranches in the surrounding district. There is no agriculture in the region, for the annual rainfall averages only about 11 inches. The village is on the wide alluvial plain of Chispa Creek, which flows northwest into Salt Basin. About 12 miles to the east are the Davis Mountains, and to the west is the high wall of the Tierra Vieja Range (ve-ay'ha), which consists of a succession of lava flows. Lavas also constitute outlying ridges in the valley beyond Valentine, as well as to the southwest of that place. Twenty miles to the south is the prominent Capote Peak, due to a thick cap of lava on tuffs dipping steeply eastward. Just west of this feature is a break in the range, through which passes the road to Candelaria and other points on the Rio Grande far south of the railroad at Valentine. Near the gap is the famous Brite ranch, established in 1885. It comprises about 225,000 acres with 65 miles of pipe lines for water supply and has a large herd of thoroughbred Hereford cattle. It was raided by Mexican outlaws in 1917, so that a fort with a powerful search light has been built, a novel feature in present ranch life. In this vicinity some rock ledges bear Indian inscriptions and pictographs of animals and people which are so deeply weathered that there can be no question as to their antiquity.

In 1931 Valentine experienced a severe earthquake, which demolished or damaged many buildings and twisted chimneys and gravestones. Apparently the settlement was near the center of the disturbance, which may have been caused by renewed movement on some of the faults that traverse the region to the south and north. The direction of the principal line of disturbance was nearly due south.

North of Wendell siding are ridges presenting a variety of rocks, mostly lavas, but also exposures of limestones and sandstones of the Trinity group (Lower Cretaceous) and a small outcrop of limestone of Permian age, which was quarried to a small extent as marble.[70] The alteration from limestone to marble has been caused by the intrusion of an igneous mass.

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[70] In the region west of Valentine strata of Cretaceous age appear in many ridges and mesas, as described by Taff, Richardson, Stanton, and Baker. They are listed in the following table:

Lower Cretaceous (Comanche) formations in western Texas

Group	Formation	Character	Thickness (feet)
Washita.	Buda limestone	Limestone, massive, light colored	30
	Del Rio clay	Buff clay, sandstone layers	100–300
	Georgetown limestone	Massive limestone, marl at base locally	100–550
Fredericksburg.	Edwards limsetone	Limestone, massive	50–600
	Comanche Peak limestone	Limestone, slabby	80+
	Walnut clay	Clay, sandstone, and impure limestone	30+
Trinity.	Finlay limestone	Limestone, mostly massive	400
	Cox sandstone	Sandstone, brown, some shale and limestone and local conglomerate.	500–2,000
	Campagrande formation	Sandstone and conglomerate	250–800

The coarse sandstones and conglomerates (Campagrande formation) at the base of the Trinity lie unconformably on the Malone formation (Upper Jurassic), and are at least 250 feet thick on the northern flank of the Quitman Mountains. The Cox sandstone, which makes up many of the high ridges near the railroad, is 1,500 feet thick in the eastern part of the Van Horn Mountains, about 2,000 feet thick in the southern part of the Quitman Mountains, and about 1,000 feet thick in the northern part of the Eagle Mountains. It consists largely of brown sandstone but includes beds of limestone and shale and local members of conglomerate. The overlying Finlay limestone is conspicuous about the Sierra Blanca and makes up the plateau extending north-

Near Quebec siding there are fine views of high ranges from 10 to 20 miles away. Those to the west are the Tierra Vieja Mountains,[71] and those to the north and east the higher summits of the Davis Mountains. The highest point of the Davis Mountains is Livermore Peak, named from a major in the United States Army, who first measured its height in 1880, when he was returning from a raid on the Apache marauders. This peak is 8,382 feet above sea level and is a part of a central intrusive mass that extends northwest to Sawtooth Peak. The succession of volcanic rocks in this region has not yet been determined, but it has a thickness of several thousand feet and presents a variety of lavas, agglomerates, and tuffs, and numerous feeder dikes and stocks by which the volcanic materials reached the surface.

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west from the Finlay Mountains, the front of which is conspicuous north of Fort Hancock. It is regarded as a formation of the Trinity group on the evidence of the fossils *Exogyra quitmanensis* and *Orbitulina texana*. The Edwards limestone is only 25 feet thick in the Van Horn Mountains and about Sierra Blanca but thickens greatly toward the south in the canyons along the Rio Grande. The overlying Georgetown limestone also thickens to the southeast and is generally overlain by Del Rio clay and Buda limestone. The Upper Cretaceous begins with a basal sandstone at most places and has a thick succession of shales with slabby limestone representing the Eagle Ford. These beds are well exposed in the southern and western parts of the Van Horn Mountains, at the southeast end of the Quitman Mountains, and northwest of the Eagle Mountains. Representatives of the overlying Austin and Taylor beds are also present, overlain by deposits of fresh-water origin in which local coal beds are included. The later part of the Cretaceous system, as explained above, is represented by sandstones and shales with interbedded volcanic tuffs and flows, the beginning of the great volcanic succession.

[71] The Tierra Vieja Mountains consist of a succession of lavas and volcanic tuffs and breccias with interbedded conglomerates, sandstones, and clays, more than 2,000 feet thick, of Tertiary age. The lavas range from obsidian to a rock of porphyritic character. One flow about 300 feet thick of the very rare volcanic rock quartz pantellerite constitutes a cliff or "rim rock," at the crest of the mountains, which presents a steep front to the west. The strata and lava sheets dip to the southeast at a low angle, mostly about 4°.

The succession of rocks in the peak at the north end of the mountains is given by Vaughan as follows (it begins a short distance below the great sheet of quartz pantellerite):

	Feet
Rhyolite	40
Clay or red sandstone	100
Rhyolite?	20±
Conglomerate and clays	80
Rhyolite breccia, light colors, hard at base	130
Conglomeratic sandstone and clay	50
Rhyolite breccia	50
Basalt (black)	65
Rhyolite and basalt breccia	6
Fine-grained material (tuff?)	60
Conglomerate and clay	80
Conglomerate, coarse	50
Rhyolite, massive, reddish	20
Sands and clays, some conglomerate	60
Sandstone and clays (at base)	40+

The sandstones and tuffs at the north end and extending along the abrupt west front of the Tierra Vieja Mountains are underlain by shales of Cretaceous age which include thin beds of coal of considerable extent. According to T. W. Stanton, the fossils in the strata just below the coal-bearing beds indicate Taylor age, The trail from San Antonio to El Paso on leaving Fort Davis swung around the foot of Livermore Peak north of Valentine and crossed Lobo Flat to the Van Horn wells, which were near the present Lobo siding. (Turn to sheet 16.)

Chispa.

Elevation 4,088 feet.
Population 18.*
New Orleans 1,043 miles.

From Chispa siding there formerly was a branch railroad (of which the grade is still visible) that passed through a gap (Chispa Summit) between the north end of the Tierra Vieja Mountains and the south end of the Van Horn Mountains and thence turned southward to the San Carlos coal mine. This mine yielded considerable coal, but apparently the enterprise could not compete with the producers of petroleum fuel. In the gap through which this branch railroad passed there is an interesting thumb-shaped plug of volcanic rock, plainly visible from Chispa siding and points beyond, which is the remains of a volcanic vent, probably of Tertiary age. The general relations in the mountain as viewed from Chispa are shown in Figure 15. The hard beds give rise to tables and cliffs and the softer strata to the intervening slopes. North of Chispa is Chispa Mountain, a sharp peak of volcanic rocks.

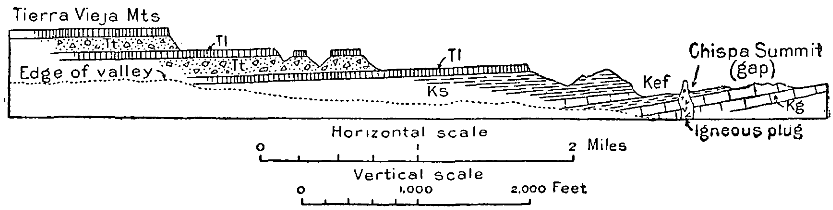
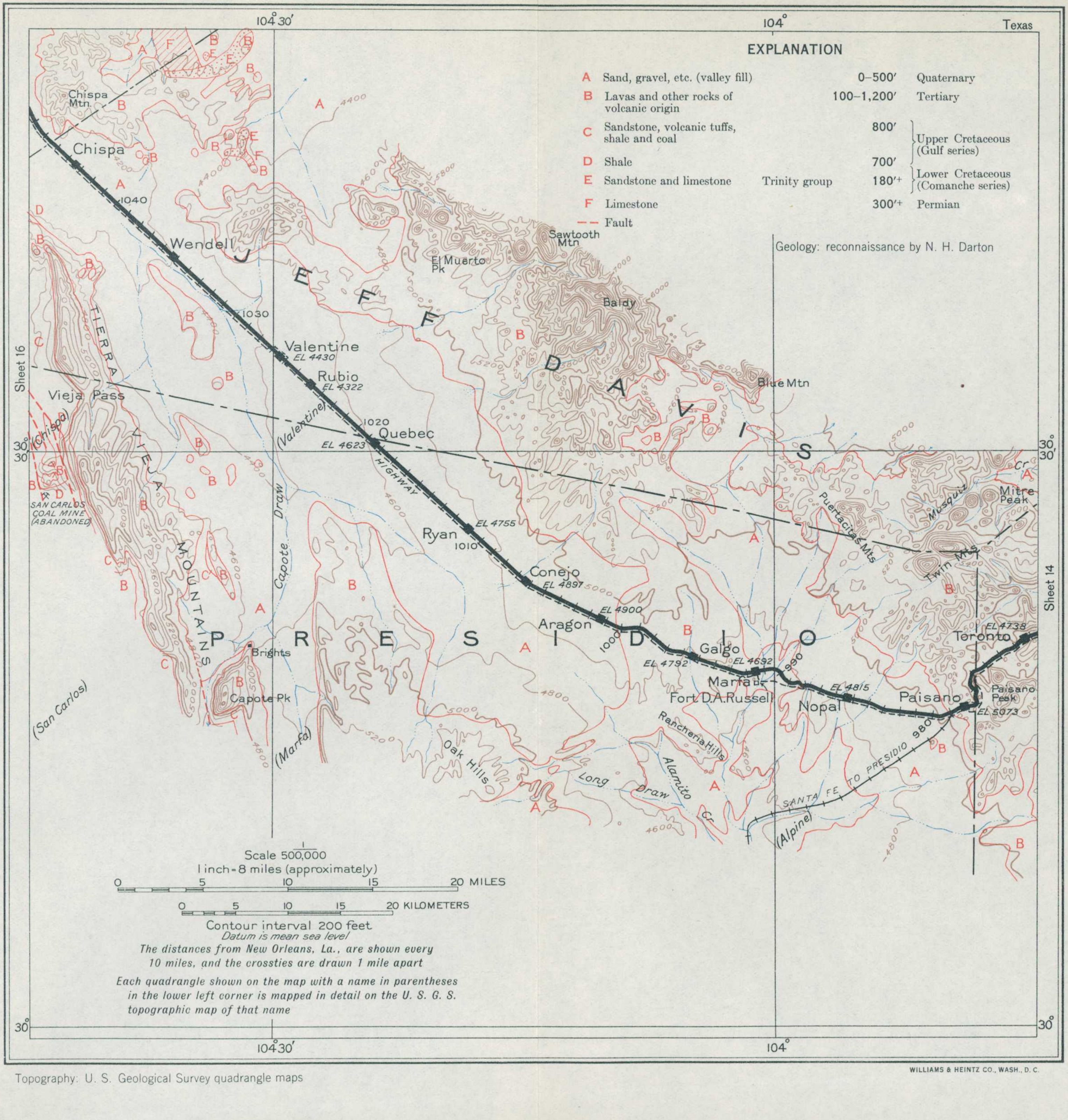


FIGURE 15.—Profile of the northern part of the Tierra Vieja Mountains south of Chispa siding, Tex. Tl, Tertiary lava; Tt, Tertiary tuff; Ks, Upper Cretaceous shale; Kef, Eagle Ford formation (Upper Cretaceous); Kg, Georgetown limestone (Lower Cretaceous)

The Van Horn Mountains,[72] which lie north of the gap west of Chispa siding, cause a long northward deflection of the railroad.

[72] The Van Horn Mountains present a wide area of strata of Lower Cretaceous (Comanche) age, overlain in the high central part and the northeast end by Tertiary volcanic rocks. The Cretaceous strata are about 2,000 feet thick, with a coarser conglomerate at the base, a thick mass of Cox sandstone above, and then representatives of the Finlay limestone and limestones of the Fredericksburg group. In the eastern part of the range the strata lie nearly horizontal, with a steplike outcrop of the harder beds. At its north end limestones of Permian age rise to the surface in the high uplift of the Van Horn region. To the south, near the gap west of Chispa, there is a strong downward pitch and downfaulting of a block consisting of a thick succession of the Upper Cretaceous rocks that make up the north end of the Tierra Vieja Mountains.

The main ridge of the Van Horn Mountains is an anticline of considerable prominence. Crossed by a fault (west to east) with drop on the north side, 8 miles northwest of Chispa, the anticline rises to the north so that the limestone of Permian age finally appears, overlapped by Trinity beds in the north end of the range. The Finlay limestone in this range consists of about 400 feet of gray earthy limestone



Topography: U. S. Geological Survey quadrangle maps

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For several miles near Danube siding the railroad is margined by a dike or levee of earth to protect the tracks from washouts. The erosion and flood-water conditions in the valleys of the arid regions are somewhat peculiar. Most of the infrequent rain falls in heavy

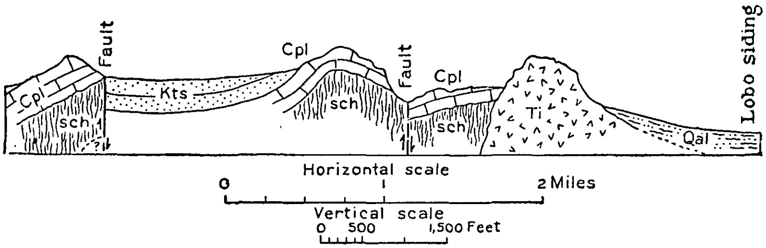


FIGURE 16.—Section across the Van Horn Mountains near their north end. Kts, sandstone Cox); Cpl, Permian limestone; sch, Carrizo Mountain schist; Qal, alluvium; Ti, igneous rock

showers, or "cloudbursts," which quickly flood the drainageways with a swiftly moving body of water sufficiently powerful to roll

containing, according to Baker, *Enallaster texanus*, *Exogyra quitmanensis*, *Gryphaea marcoui*, *Requienia*, and *Tylostoma*. The Edwards limestone is thin in the Van Horn Mountains, apparently comprising only 25 feet of beds at the south end of the range, near Chispa Summit. It is a massive bluish rock grading down into some slabby beds supposed to represent the Comanche Peak and Walnut clay. The representative of the Georgetown in this area consists of nodular limestone and marl underlain by a bed of brown sandstone and capped by a heavier-bedded limestone, in all about 500 feet. In exposures 9 miles southwest of Lobo siding there have been collected from this formation, according to Baker, *Pervinquieria graysonensis*, *P. wintoni*, *Holaster simplex*, and *Holectypus limitis*. At the fault 3 miles west of Chispa Summit the sandstone noted above lies on Edwards limestone and is overlain by nodular impure blue-gray limestone of Georgetown age, which carries *Enallaster texanus*, *E. bravoensis*, *Hemiaster calvini*, *Holectypus planatus*, *Kingena wacoensis*, *Neithea texana*, *Cypricardia texana*, and *Gryphaea corrugata*. These beds are overlain by slabby limestones and shales of the Eagle Ford formation, which are highly fossiliferous at Chispa Summit, where besides the characteristic *Inoceramus labiatus* many fine ammonites have been collected. These include, according to Adkins, *Mantelliceras* aff. *M. couloni* (D'Orbigny), *Romaniceras cumminsi* Adkins, *R. loboense* Adkins, *Coilopoceras eaglefordense* Adkins, *C. chispaense* Adkins, *Pseudoaspidoceras? chispaense* Adkins, *Fagesia texana* Adkins, *Thomasites* sp., *Neoptychites* aff. *N. gourguechoni* Pervinquière, *Hoplitoides? mirabilis* Böse, *Neocardioceras septem-seriatim* (Cragin), *Scaphites* aff. *S. africanus* Pervinquière, *S.* aff. *S. aequalis* Sowerby, and *Metaptychoceras* aff. *M. smithi* (Woods).

These fossiliferous strata pass under shales with thin limestone layers equivalent to the Austin chalk, and these in turn are overlain by shales of Taylor age, which are exposed far to the south along the west side of Tierra Vieja Mountains to and beyond the San Carlos coal mine. At this mine, according to Dumble, they carry *Nautilus dekayi?*, *Schloenbachia delawarensis*, *Baculites asper*, *B. ovatus*, *Placenticeras guadalupae*, *Ostrea elegantula*, *Exogyra costata* var., *Trigonia thoracica*, *Cardium alabamense*, and many others—a fauna which is regarded by Stanton as lying between the Navarro and the Austin limestone. A good specimen of a tooth of *Ptychodus mortoni* Agassiz was found.

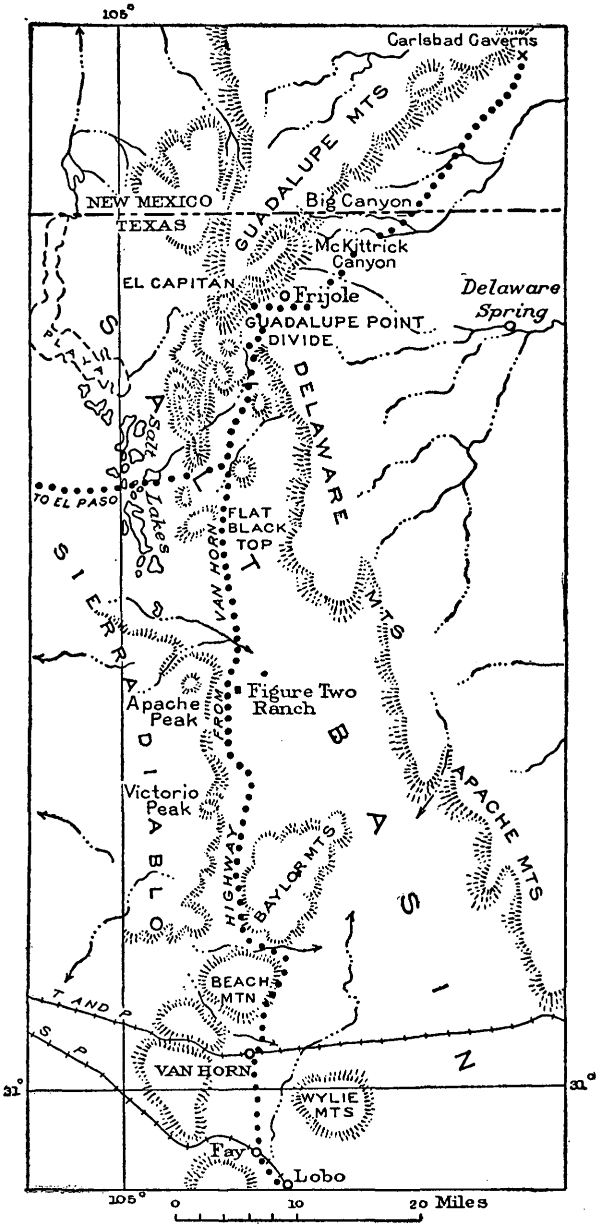
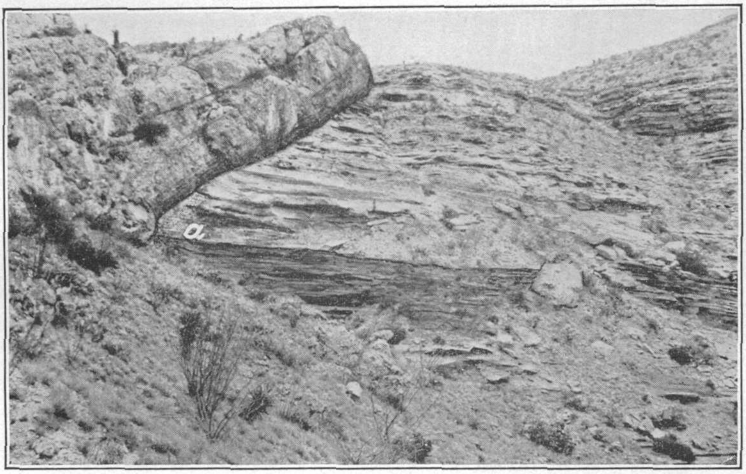
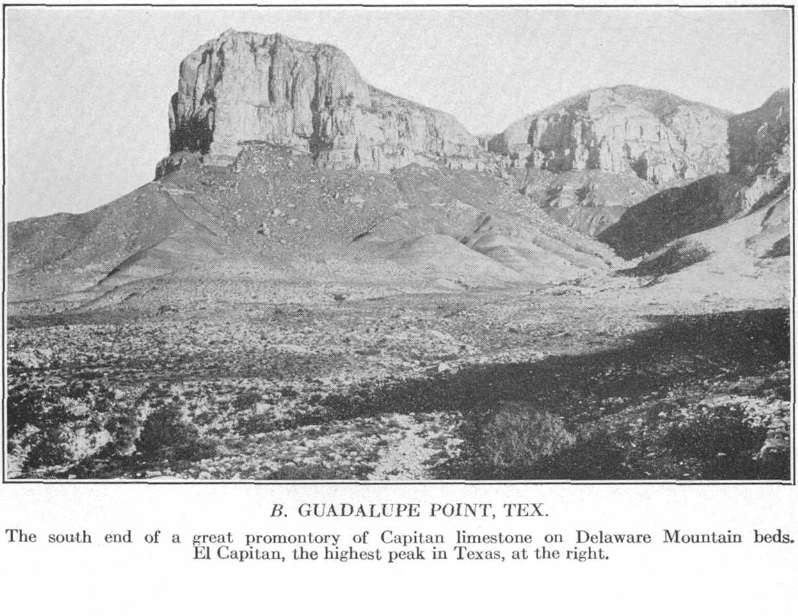


FIGURE 17.—Map showing route from Lobo, Tex., to Carlsbad Caverns, N. Mex.



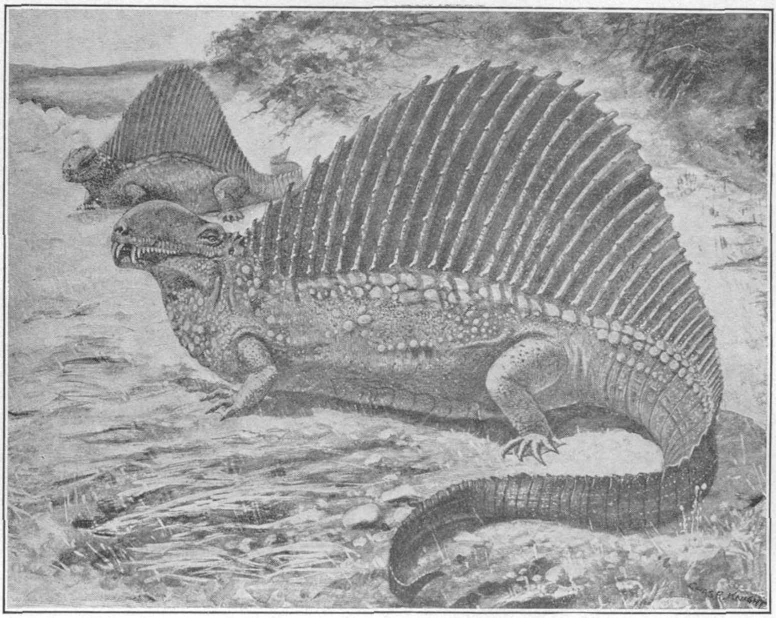
A. PERMIAN LIMESTONE LYING UNCONFORMABLY ON EL PASO LIMESTONE AT SOUTH END OF BAYLOR MOUNTAINS, 12 MILES NORTH OF VAN HORN, TEX.

a. Contact of Van Horn sandstone.



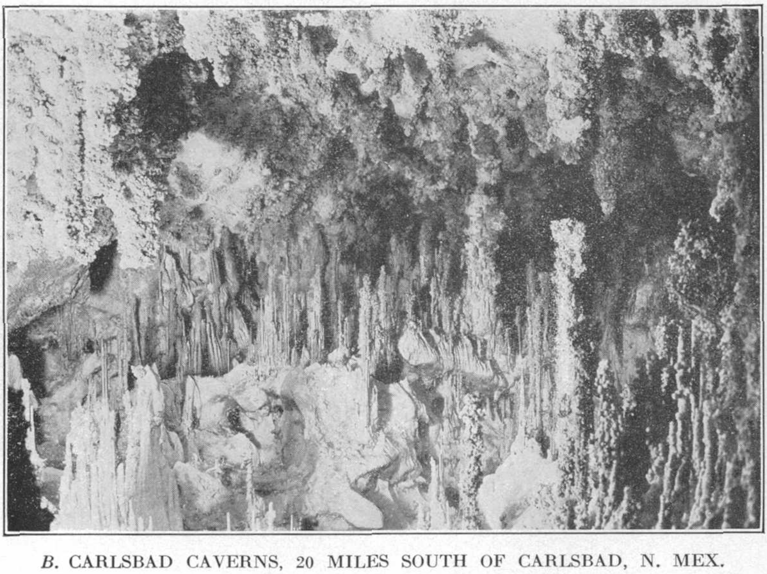
B. GUADALUPE POINT, TEX.

The south end of a great promontory of Capitan limestone on Delaware Mountain beds. El Capitan, the highest peak in Texas, at the right.



A. FINBACK LIZARDS OF PERMIAN TIME

Restoration from bones of *Dimetrodon incisivus* and *Naosaurus claviger* found in the "Red Beds" of Texas. They range in length from 3 to 10 feet and are among the earliest forms of saurian life.



B. CARLSBAD CAVERNS, 20 MILES SOUTH OF CARLSBAD, N. MEX.

Deposits of calcium carbonate. (National Park Service.)

large boulders and to transport a vast amount of fine material far down the side slopes. These floods often cut deeply into the railroad embankments, so that it is necessary to provide long deflection ditches and dikes to prevent serious washouts. This item is as expensive as flood protection and repair in regions where there are large rivers subject to freshets. The run-off is very rapid in the deserts, because the rocks are bare, the soil is hard, and most of the slopes are steep. But little water passes underground, and springs, even in the mountains, are exceedingly rare. Much water, moreover, is lost by evaporation.

Lobo.
Elevation 3,943 feet.
Population 30.*
New Orleans 1,054 miles.

At Lobo are wells which afford water for locomotive supply and local use. A noticeable feature here is a large stone building erected by the railroad company as a hotel; it did not succeed, however, and is now used as a ranch house. The prominent mountain about 7 miles east of Lobo consists of quartz syenite of igneous origin, and there is another large intrusion of this rock in the northeastern part of the Van Horn Mountains just west of Lobo. It was forced in molten condition into strata of Permian and Lower Cretaceous age, probably in early Tertiary time.

SIDE TRIP TO CARLSBAD CAVERNS, N. MEX.

At Lobo passengers can make arrangements for motor transportation to Carlsbad Caverns by way of Van Horn, a distance of about 100 miles nearly due north. The route is shown in Figure 17. There are regular busses and a 1-day airplane excursion from El Paso to the caverns, a distance of 140 miles. The caverns are on the southeast slope of the Guadalupe Mountains and extend far and deep underground in a series of superb chambers containing a great variety of beautiful stalactites, stalagmites, and other depositional forms of calcium carbonate. (See pl. 16, *B*.) The road northward from Van Horn skirts the outlying ridges of Beach and Baylor Mountains and the foot of the Sierra Diablo, on the west side of Salt Basin, a wide desert valley of which the Lobo Flats are a southern extension. This valley is without outlet. The mountains adjoining it consist mainly of limestones and sandstones lying nearly horizontal and presenting a most interesting succession of 5,000 feet or more of

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Paleozoic strata, with the underlying pre-Cambrian sandstones, limestones, and schists exposed to the south.[73]

[73] The principal features of the formations in this region are given in the following table:

Formations in the Van Horn region

Age	Formation	Character	Thickness (feet)
Cretaceous.		Sandstone and limestone.	1,800+
Permian.		Limestone, mostly massive, light to dark, many reefs. (Lies unconformably on older strata down to pre-Cambrian.)	2,800
Pennsylvanian.		Limestone, massive, on dark shale.	800
Devonian?.		Chert and dark slabby shale.	150
Silurian.	Fusselman.	Dolomite, massive, light.	100+
Ordovician.	Montoya.	Limestone, cherty, with basal brown sandstone member.	400
	El Paso.	Limestone, massive, mottled, lower part sandy.	1,000
Upper Cambrian.	Van Horn.	Sandstone, red arkose conglomerate lenses and basal member. (Lies unconformably on pre-Cambrian.)	50-700
Pre-Cambrian.	Millican.	Limestone, massive, thinly banded with chert; carries masses of *Cryptozoon*. Sandstone, red, in part argillaceous and conglomeratic. Conglomerate, including schist fragments. Cut by sills of diabase and carries interbedded lava flows.	3,000±
	Carrizo Mountain.	Schist and gneiss cut by igneous rocks and veins of quartz and pegmatite.	

The pre-Cambrian schist constitutes the Carrizo Mountains, which lie between the Texas & Pacific and Southern Pacific Railroads west of Van Horn. It is also exposed in a few small areas in the adjacent region. The Millican formation, which contains much red shale and cherty limestone, resembles the Grand Canyon series and Apache group of Arizona. It constitutes an area of foothills northwest of Van Horn. Although undoubtedly it is younger than the schist, the two formations are separated by faults, a feature well exposed a short distance north of Eagle Flat station on the Texas & Pacific Railway, where the limestone of Permian age overlaps both. The presence of schist fragments in the conglomerate and the lesser degree of metamorphism of the Millican beds indicate that they are younger than the schists, doubtless of Algonkian age. The Van Horn sandstone lies on an irregularly eroded surface of the pre-Cambrian rocks. It is several hundred feet thick in the ridges northwest of Van Horn, but it thins out in places, together with the overlying old limestones, so that the limestone of Permian age lies directly on the Millican formation or on schist. In part of the area the Permian limestone lies directly on El Paso limestone, as shown in Plate 15, *A*. In places the Van Horn beds, especially the lower ones, consist largely of coarse material including fragments of red granite and porphyry of pre-Cambrian age which probably formed a shore near by, now covered by later sediments. Much of the Van Horn material is of red color. The succession of El Paso to Fusselman limestone which largely constitutes Beach Mountain and some of the foothills about the Baylor Mountains, north of Van Horn, is very similar to the formations in the Franklin Mountains north of El Paso and contains the

The Sierra Diablo is an elevated plateau sloping gently westward and presenting to the east an imposing escarpment 2,000 to 2,500 feet high. Its highest summit, Victorio Peak, is 6,432 feet above sea level. It is due to an uplift by which the strata were raised several thousand feet by a long south to north fault or zone of faults that extends along its foot. In places the downfaulted strata are exposed dipping steeply to the east, as shown in Figure 18, and in the slopes 25 miles north of Van Horn there are small but steep escarpments in the alluvial fan, which probably indicate recent movements along this fault zone.

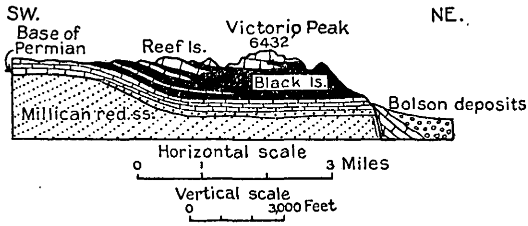

FIGURE 18.—Section of east front of Sierra Diablo at Victorio Peak, 18 miles north of Van Horn, Tex. By P. B. King

same fossils. Some of them can also be correlated with strata in the Marathon uplift. These limestones thin out to the south and west. They also appear in the foot of the Sierra Diablo, 25 miles north of Van Horn, just west of the road to the Carlsbad Caverns. The Fusselman limestone contains a characteristic *Pentamerus;* the Montoya contains *Columnaria, Halysites, Streptelasma, Rhynchotrema,* and *Rafinesquina* of the Upper Ordovician; and the El Paso limestone contains *Piloceras, Eccyliomphalus, Hormotoma,* and *Ophileta* of the Lower Ordovician.

The Permian succession that constitutes the great mountain block of the Sierra Diablo, the Baylor and Wylie Mountains, and some minor ridges consists mostly of limestones of various kinds presenting considerable variety of fossil assemblages. The thickness remaining in the high eastern front of the Sierra Diablo is 2,700 feet. During Permian time there was nearly continuous subsidence and deposition in the region, uninterrupted by uplift or extensive incursions of coarse sediments. Evidently there were long reefs which persisted during the deposition of thousands of feet of strata. The position and extent of land at that time in the general region are not known. These reefs had a controlling effect on the sedimentation. In the open sea in front of them were deposited materials now represented by flaggy black limestones, siliceous shales, and fine sandstones which contain such Guadalupian fossils as *Richthofenia* and *Leptodus.* Behind the reefs were lagoons in which were deposited sediments now represented by thinly stratified dolomite containing fusulinids in extreme abundance. Farther behind, to the west and southwest, there were accumulations of limy sediments with a fauna like that in the Hueco Mountains, including *Omphalotrochus, Bellerophon, Productus peruvianus,* and *Spirifer condor.* The reefs consist of very massive limestones or dolomites, built of the remains of algae, bryozoans, sponges, crinoids, and other fossils adapted to reef environment.

The Permian of the Wylie and Baylor Mountains consists of limestones laid down behind the reefs. In the Sierra Diablo a thick body of lagoon limestone constituting the lower third of the series is succeeded by black limestone and other open-sea deposits cropping out in rounded slopes, which are surmounted by great cliffs of the reef limestone. Some of the relations of these strata are shown in Figure 18. In places in the escarpment there is an abrupt transition from black limestone to reef limestone. At the north end of the Sierra Diablo, 40 miles northwest

To the southwest the Sierra Diablo is separated from Salt Basin by Beach Mountain and the Baylor Mountains, fault blocks both, the latter having the relations shown in Figure 19.[74]

About 35 miles north of Van Horn, not far beyond the Figure Two ranch, the road to the Carlsbad Caverns passes the north end of the Sierra Diablo, where the northerly dip of the great limestone succession carries it rapidly below the surface. In the next few miles the Salt Basin is crossed diagonally and the westward-fronting escarpment of the Apache and Delaware Mountain range is gradually approached. This range consists of limestones and sandstones of Permian age, which also constitute various outlying buttes. Very prominent features to the north are the high white promontory of Guadalupe Point (see pl. 15, *B*), at the south end of the Guadalupe Mountains, and El Capitan, the culminating peak of that range and the highest summit in Texas (elevation about 8,700 feet). These mountains are capped by a thick succession of light-colored limestone (Capitan limestones) of Permian age which extends to the Carlsbad Caverns. It

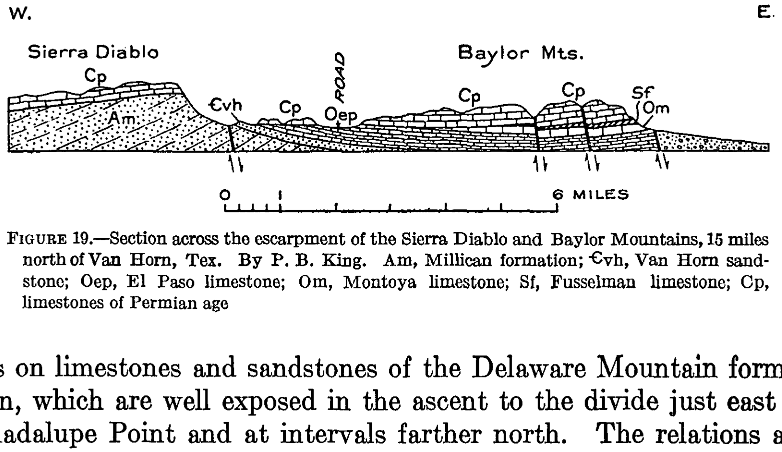

FIGURE 19.—Section across the escarpment of the Sierra Diablo and Baylor Mountains, 15 miles north of Van Horn, Tex. By P. B. King. Am, Millican formation; Ꞓvh, Van Horn sandstone; Oep, El Paso limestone; Om, Montoya limestone; Sf, Fusselman limestone; Cp, limestones of Permian age

lies on limestones and sandstones of the Delaware Mountain formation, which are well exposed in the ascent to the divide just east of Guadalupe Point and at intervals farther north. The relations are shown in the sections in Figure 20. It will be seen from the first of

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of Van Horn, the reef limestones are overlain by sandstones of the Delaware Mountain formation, a remnant of the thick succession of pre-Capitan strata well developed in the Delaware and Apache Mountains, on the east side of Salt Basin. (P. B. King.)

[74] In these mountains the Permian limestones are separated from the Millican beds (pre-Cambrian) by Fusselman, Montoya, and El Paso limestones and Van Horn sandstone, occupying a local basin of moderate size. There are overlaps of the various formations. Several faults trending northwest cross the southern part of the Sierra Diablo region and it is through a gap along one of these breaks that the Texas & Pacific Railway crosses the range west of Van Horn. In this gap the Permian limestone, capped in places by strata of Comanche age, lies directly on the Van Horn sandstone. The Comanche beds here consist mainly of sandstone with some conglomeratic layers and a few thin layers of limestone. At the base is a 1-foot bed of conglomerate overlain by 10 to 20 feet of impure limestone. About 400 feet remains, an unknown amount of overlying strata having been removed by erosion.

these sections that the caverns are in the Carlsbad limestone member, which is a northern extension of the upper part of the Capitan limestone. The strata dip to the east. The opening is on the east slope of the mountains, some distance above the plain underlain by Castile gypsum which here skirts the east foot of the mountains. The opening is a wide natural arch from which a broad stairway and an elevator descend into the cavern, which has a total depth of more than 700 feet. Some of the upper chambers of the cavern are the homes of myriads of bats, which fly out for a nightly foray at sunset every evening in a veritable cloud of wings that darkens the sky; they return at dawn. Many visitors linger in the evening to see the exodus.

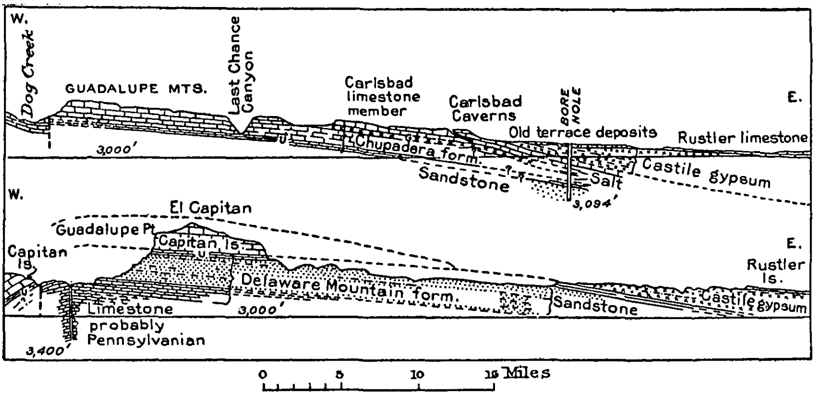

FIGURE 20.—Sections across the Guadalupe Mountains at El Capitan, Tex., and Carlsbad Caverns, N. Mex.

LOBO TO EL PASO, TEX.

Three miles beyond Lobo State Highway 3 crosses the Southern Pacific tracks and goes to Van Horn, a small town on the Texas & Pacific Railway, dimly visible down the valley, about 8 miles to the north. The old military trail from the east followed the Lobo Flats to Van Horn Wells, thence north and west to Eagle Spring, Fort Quitman, and San Elizario on its way to El Paso, whence a trail continued on into Chihuahua.

East of Fay are the Wylie Mountains,[75] a deeply dissected elevated plateau of limestone of Permian age cut off on its west side by a fault, as shown in Figure 21.

Many chapters of geologic history are indicated by the rocks of western Texas. Although some of the conditions and events are clearly shown, some intervals of geologic time are not represented by

[75] The limestone of this range is the same as that which caps the Sierra Diablo north of Van Horn. The schist exposed on the west face of the Wylie Mountains is composed of light-pink quartz-muscovite schist, quartz-biotite-muscovite schist, chlorite schist, and amphibolite schist, with quartz veins and lenses. The strike is nearly east and the dip 20°–30° S. (Baker.)

sediments. The old basement of schist and granite of pre-Cambrian time appears in the Van Horn and El Paso regions, where in places it is overlain by sandstone and limestone probably of Algonkian age. The relation of land and sea and the extent to which Algonkian deposits were laid down can be only vaguely pictured. Late in Cambrian time there was extensive marine submergence, with shores on which accumulated the sand of the Bliss and Van Horn sandstones. In the next period (Ordovician) there were widespread marine conditions from time to time, separated by intervals of general uplift in which doubtless some deposits were removed by erosion. This oscillation of submergence and emergence continued through the Paleozoic era, but representatives of part of the Silurian, Devonian, Mississippian, and Pennsylvanian are all indicative of widespread marine seas, most of the shores of which can not be located. In these times the uplifts were general and in greater part not attended by flexing until late

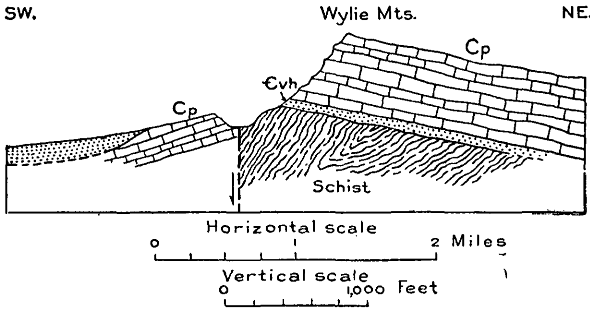

FIGURE 21.—Section across the western part of the Wylie Mountains north of Lobo siding, Tex. Cp, Permian limestone; Ꞓvh, Van Horn sandstone (Cambrian)

Pennsylvanian time, when arching and considerable crustal fracturing occurred in many if not all parts of the general region. The erosion that ensued removed considerable material and reduced the surface to a rolling and in places rugged upland, in which rocks of pre-Paleozoic to Pennsylvanian age were exposed. Some of this old upland surface is revealed in the Marathon and Van Horn regions. In widespread and long-continued marine submergence in Permian time southwestern Texas and the adjoining regions were covered with limy sediments, which in part of the area had a thickness of 5,000 feet or more. In places the deposition was long continued, subsidence keeping pace with the accumulation of the fine sediments. Local conditions varied greatly. In some places there were extensive barrier reefs near the borders of the sea and persisting throughout the deposition of thousands of feet of strata. These reefs consist of massive limestones or dolomites, such as those in the Guadalupe, Diablo, Apache, and Glass Mountains, and contain remains of algae, bryozoans, sponges, crinoids, and other fossils of reef habitat. Behind the reefs were wide lagoons in which thinly stratified beds were laid down, some of them porous limestones and locally clays, red beds, and gypsum. (P. B. King.) A great interval of sand deposition is indicated by the sandstone of the Delaware Mountain formation. In part of the region extensive mud flats of red clay were built on lowlands subject to overflow, and in some of the shallow intervening basins there was a thick accumulation of salt and gypsum. On the adjoining lands lived many animals, largely strange reptiles, of which many remains have been found in the Permian red beds. One of the most peculiar of these animals, the finback lizard, is shown in Plate 16, *A*.

After Permian time there was widespread uplift with considerable flexing of the strata and extensive erosion. In certain local basins limy sediments were laid down, as shown by the thick mass of Jurassic limestone of the Malone Mountains, the product of a sea or marine estuary. Through the Cretaceous period there were several marine occupations of wide extent and long duration, in which the Comanche strata (Lower Cretaceous) and the clays and chalks of the Upper Cretaceous were accumulated. Late in Cretaceous time, however, western Texas was elevated above the sea, and it has been an upland ever since. Volcanic action began at this time, with the ejection of tuffs and ash and thin flows of acid lava, the earliest of which were buried by sand. Later there were tremendous eruptions of lavas of many kinds, with the building of high volcanic cones, some of cinder and scoria, which continued into Tertiary and later time. There was in late Tertiary time a widespread uplift in which the lavas were tilted, flexed, and faulted. Since then they have been widely removed and sculptured by erosion to their present forms, and thick mantles of alluvium have been deposited in some of the valleys.

The Lobo Flats support much tobosa grass, a plant that carries its moisture a long time and is therefore in high favor for pasture. This wide valley was a favorite rendezvous for Apache Indians and outlaws, who committed many depredations. At Fay siding a 2,012-foot boring found but little water. Beyond Fay siding the railroad passes around the north end of the Van Horn Mountains, an outlying knob of the Permian limestone reaching the railroad at milepost 702, 2 miles beyond the siding. At Collado siding, 2 miles farther on, the railroad deflects around a knob of the same limestone at the south end of the Carrizo Mountains.[76]

[76] These mountains consist mainly of Carrizo Mountain schist (pre-Cambrian), with small overlapping areas of Van Horn sandstone (Upper Cambrian), capped by limestone of Permian age. The Van Horn sandstone varies in thickness but in places is more than 200 feet thick, consisting of red micaceous sandstone with a basal conglomerate of schist and quartz. The Carrizo Mountain schist extends north to the gap in which the Texas & Pacific Railway crosses the range west of Van Horn. According to Baker, the schist is well exposed in Bass Canyon, north of Dalberg siding, where it strikes northwest and includes mica schist, quartz schist, and chlorite

From Collado siding there is a branch railroad south to the Microlithic quarry, 5 miles distant, where mica and feldspars of various colors are obtained from a coarse pegmatitic rock in Carrizo Mountain schist of pre-Cambrian age in the northwestern slope of the Van Horn Mountains.[77] The occurrence of this old rock at this place is due to a north-northwesterly fault that brings up a block of the schist, Van Horn sandstone (150 feet thick), and limestone of Permian age on the west against limestones of Trinity age (Lower Cretaceous) on the east. To the south from Dalberg siding and vicinity there is a good view down the wide valley between the Van Horn and Eagle Mountains to the Rio Grande, 40 miles distant. Some years ago there were in this valley at a place about 8 miles south of the railroad, some deep cracks in the ground that were attributed to an earthquake. They trended north and south and cut clays in the arroyo and gravel on the benches. From Collado siding to Hot Wells and beyond there are fine views of the high, craggy Eagle Mountain to the west, a huge pile of lavas and other volcanic rocks of Tertiary age,[78] in which the highest point is 7,510

schist, with lenses and veins of quartz and dikes of dark-green basic intrusive. Some of the schists contain garnet.

The Carrizo Mountains are near the center of a large, irregular uplift in which the strata and underlying crystalline rocks are raised to their maximum elevation in Texas. In Hackett Peak, near the center of these mountains, the Carrizo Mountain schist has an elevation of 5,280 feet in an area that has been considerably denuded by erosion. The uplift is traversed by many large faults, some crossing nearly north and south and others east and west, and on its southwest side there is an overthrust of considerable amplitude. The movements have taken place at intervals from late Cretaceous to middle Tertiary time. A fault of 300 or 400 feet displacement along the west side of the Wylie Mountains (see fig. 21) and the fault at the mica mine south of Dalberg siding are good examples of north-south displacements, and there are several transverse faults west and southwest of Van Horn. The south slope of the uplift is well exhibited in the northern part of the Van Horn Mountains, in which limestones of Permian age and the overlying Cox sandstone rise gradually to the north.

[77] The pegmatites at this place present great variety in color and composition, and some of the dikes are 100 feet wide. They range from graphic granite, an intimate intergrowth of feldspar and quartz, to crystals of feldspar and mica a foot or more in size. The feldspar varies in shade from flesh-color to pearly white. Large tabular masses of black tourmaline occur in places and some crystalline hematite. The schists are of many kinds; the prevailing type is a finely foliated aggregate of muscovite and flesh-colored or white feldspar, but some carry feldspar, biotite, and garnet. The average general dip of the foliation appears to be east, but it swings in various directions. There is considerable vein quartz, mostly milky white. (Baker.) The various minerals are separated at this quarry and used for facing concrete blocks and other construction materials.

[78] The volcanic rocks of Eagle Mountain lie on an irregular platform of sandstone and limestone of Trinity age (Comanche) with Permian limestone and pre-Cambrian schist in the lower northeasterly slopes. According to Baker, these pre-Cambrian rocks are quartz and amphibole schists, quartz-

feet above sea level, or about 3,000 feet above the valley followed by the railroad. It was in this range that after the death of Victorio at Tres Castillos, Mexico, the survivors of his band of Apaches had their last hiding place; they were finally caught by Captain Baylor and the Texas Rangers near Victorio Peak, 25 miles north of Van Horn.

Hot Wells.
Elevation 4,285 feet.
Population 50.*
New Orleans 1,073 miles.

At Hot Wells hot water obtained from borings 1,000 feet deep in the valley fill is used for the treatment of rheumatism and other ills. The water must come from a considerable depth, probably along a fault plane under the valley fill, which is thick in this valley.[79] Eagle Spring, at the foot of Eagle Mountain, about 5 miles west-southwest of Hot Wells, is a noted watering place for cattle, and in earlier days for travelers on the old trail.[80]

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ites, and a very basic dark-green intrusive cut by quartz veins, one of which contains some copper minerals. The strike is N. 70° E., and the dip is steep to the south and southeast. A cross fault, trending west-southwest, cuts off the strata to the north. On the north foot of the mountain are exposed a considerable body of Trinity strata overlain by Washita and Upper Cretaceous beds.

[79] The ordinary rate of temperature increase underground is 1° for every 60 feet. At most places in this region a temperature of about 140° is to be expected at a depth of about 4,000 feet. The presence of volcanic rocks not yet fully cooled, or of special conditions in the earth's crust, however, may greatly increase the rate, which is found to vary somewhat from place to place.

[80] Eagle Spring is on a fault between the Campagrande formation and Finlay limestone. The Campagrande beds at this place, according to Baker, comprise about 800 feet of strata, mainly sandstones with a minor amount of conglomerate and several thin beds of limestone, one of which near the base contains the Trinity fossil *Porocystis pruniformis*. (For table of these formations see p. 100.) Several sills of intrusive rock are present, and a great dike of rhyolite half a mile north of Eagle Spring has changed the limestone (Permian), which it penetrates, into marble for a distance of 25 feet from the contact.

The east slope of Eagle Mountain south of Hot Wells presents the entire Trinity group lying on Carrizo Mountain schist. The Finlay limestone here forms a great platform on which is piled the thick succession of volcanic rocks constituting the upper part of Eagle Mountain. These rocks are mostly rhyolite, with some interbedded tuffs and conglomerates lying on a great thickness of tuff breccias. Bones of land tortoises occur here in rhyolite tuffs.

A sandy limestone weathering brown, about 500 feet above the base of the succession, is regarded as Finlay. It carries *Exogyra quitmanensis* and includes some conglomeratic sandstone and some sandy shale members. In the anticline between the overturned strata at the north end of the mountain there are ledges of dove-colored cherty limestone, then a débris-covered interval to 200 feet of dark-gray clays with interbedded limy clays, extending to nodular earthy limestones. The cap rock of the hogback ridges north of the main fault is heavy-bedded Finlay limestone, and this caps nearly all the hogback ridges extending northward to Sierra Blanca and Etholen except the main Devil Ridge. Most of these ridges are conspicuous from the railroad. The Cox sandstone appears to be absent here, or perhaps is faulted down. (Baker.)

A thin bed of coal occurs in sandstone and shale members of the Finlay lime-

Near Torbert siding the valley is very wide, extending north to and beyond the Texas & Pacific Railway. It contains much grass and many yuccas. Far to the north is a long line of cliffs of limestone (Permian) forming the southern margin of the Sierra Diablo.[81]

Sierra Blanca.

Elevation 4,518 feet.
Population 723.
New Orleans 1,095 miles.

Sierra Blanca is at the junction of the Southern Pacific and Texas & Pacific lines (p. 293) and on State Highway 1, which crosses southwest Texas. In the vicinity are extensive cattle ranches, and considerable prospecting has been done on the adjoining mountains, but without very encouraging results. The dominant feature of the landscape is the high conical mountain about 8 miles distant, called Sierra Blanca through a perversion of the Mexican name "Cerro Blanco" (white hill). Its elevation is about 6,970 feet. It consists of a huge body of rhyolite, a fine-grained, nearly white rock that has welled up as a viscous mass from a fissure in the earth's crust. The rhyolite lies on a platform of limestone of Washita age, which on the west side is penetrated by a large sill of a darker, coarser intrusive rock (trachyte), probably older than the rhyolite and similar in character to the large lens-shaped intrusive mass that

---

stone half a mile south of Eagle Spring, southeast of the fault. It is 3 feet thick, dips 80° N. 15° E., and has been altered to a semianthracite by the heat of a great intrusion of igneous rhyolite which has also changed some of the limestones into marble. A short distance up the arroyo, above the old coal pit, heavy beds of limestone carry *Exogyra quitmanensis* and *Orbitulina texana*. Farther up is the tuff breccia of the great volcanic mass. A mile to the northwest are exposures of shale, sandstone, and *Orbitulina*-bearing limestone, which crop out at intervals for 3 miles west along the south side of the fault.

At the north end of Eagle Mountain there are exposures of about 550 feet of limestones regarded as Georgetown, overlain by 100 feet of hard brown sandstone, probably Del Rio. This is capped by fine-grained chalky limestone referred to the Buda, and dark blue-gray and drab shale with some sandy and limy layers, the latter containing *Inoceramus labiatus* and other fossils of the Eagle Ford formation.

At Carpenter Spring, 4 miles south-southwest of Eagle Spring, considerably below the volcanic materials and probably on the other limb of a syncline, is several hundred feet of shale underlain by limestone, all believed to be Finlay. This limestone also occurs on the northeast side of Eagle Mountain, where it contains some brown sandstone and shale and has yielded, according to Baker, the fossils *Orbitulina texana*, *Enallaster texanus*, *Pecten subalpina*, and *Tylostoma* sp.

[81] Just south of these cliffs is a long west-east fault south of which is exposed a thick succession of limestones and red shales of Algonkian(?) age (Millican formation) dipping steeply in various directions. Some of the relations are shown in Figure 22. This formation is believed to overlie the Carrizo Mountain schist, and it is overlain unconformably by the Van Horn sandstone (Cambrian) and the Permian limestones. These limestones also cap high mesas and buttes north of Bola siding, one of the most prominent of which is Eagle Flat Butte, just north of the Texas & Pacific Railway. Southwest of Bola siding are ridges of strata of Comanche age, mostly limestone and sandstone of the Trinity group, constituting the Devil Ridge, which parallels the railroad for 15 miles or more.

uplifts limestone of Trinity age in Triple Hill. There are two other conical masses of rhyolite a short distance north and northwest of the large one, but they are of much less height.[82]

Just north of Sierra Blanca is a long ridge of limestones and sandstones of Trinity age penetrated by small bodies of intrusive rocks and apparently cut off on the east side by a fault. This ridge extends north to Triple Hill.

South of Sierra Blanca are other high ridges of the same limestones and sandstones.[83]

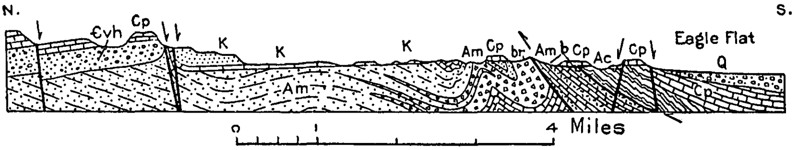


FIGURE 22.—Section from the southern edge of the Diablo Plateau to Eagle Flat, east of the Sierra Blanca, Tex. By P. B. King. K, Sandstone and limestone (Cretaceous); Cp, limestone (Permian); Ꞓvh, Van Horn sandstone (Cambrian); Am, Millican formation (Algonkian), including breccia (br) and diabase (b); Ac, Carrizo Mountain schist; Q, Quaternary sand and gravel

There has been difficulty in obtaining an adequate water supply for Sierra Blanca, but in 1930 a well about a mile east of the town struck water, apparently either in a sandstone low in the Trinity

[82] The rock of Sierra Blanca and the similar smaller cones is classed as rhyolite, as it is composed mainly of quartz, orthoclase, and sodic plagioclase. The phenocrysts are orthoclase, oligoclase, and small amounts of quartz and hornblende. The intrusive trachyte is a porphyritic rock composed mainly of sodic plagioclase and hornblende with phenocrysts of oligoclase and hornblende in a groundmass of essentially the same minerals. These rocks were determined by C. S. Ross, of the United States Geological Survey.

[83] High on the ridge 3 miles southwest of Sierra Blanca the limestones contain an abundance of *Orbitolina texana*, a a small disk-shaped fossil characteristic of the upper part of the Trinity group. A mile southwest of Sierra Blanca the limestone has been metamorphosed by intrusive sills, and secondary minerals, such as garnet, hematite, and specularite, have been developed. The strata (Cox) underlying the limestones (Finlay) in the hogback ridges in this vicinity are light green-brown medium-grained sandstones with thin limestone members at intervals, passing into medium-bedded gray limestones with interbedded greenish sandstones, in all 750 feet thick. In the large ridge 3 to 5 miles south of Sierra Blanca the cap of Finlay limestone is underlain by 1,000 feet of limestones, sandstones, and conglomerates, some thin bedded, of the Cox formation. At the northeast base of the ridge just south of Sierra Blanca are sandstones with a few interbedded limestones, all Cox. (Baker.)

The large mesa 5 miles south of Etholen is capped by massive limestone (Finlay) containing *Orbitolina texana*, and about 200 feet above the base of this limestone is an interbedded brown sandstone with green chert and silicified wood near its base. Bluff Mesa, to the east of this feature, is also capped by heavy limestone (basal Finlay) about 200 feet thick, with a thick breccia at the top containing *Exogyra quitmanensis*. Other fossils in this limestone, according to Baker, are *Orbitolina texana*, *Pecten*, *Pholadomya* and *Alectryonia*.

group or coming from a fault fissure that appears to cross the valley in that vicinity. About 31 miles to the south, on the bank of the Rio Grande, are the Indian Hot Springs, a noted resort which utilizes the hot water for remedial purposes.

Etholen.

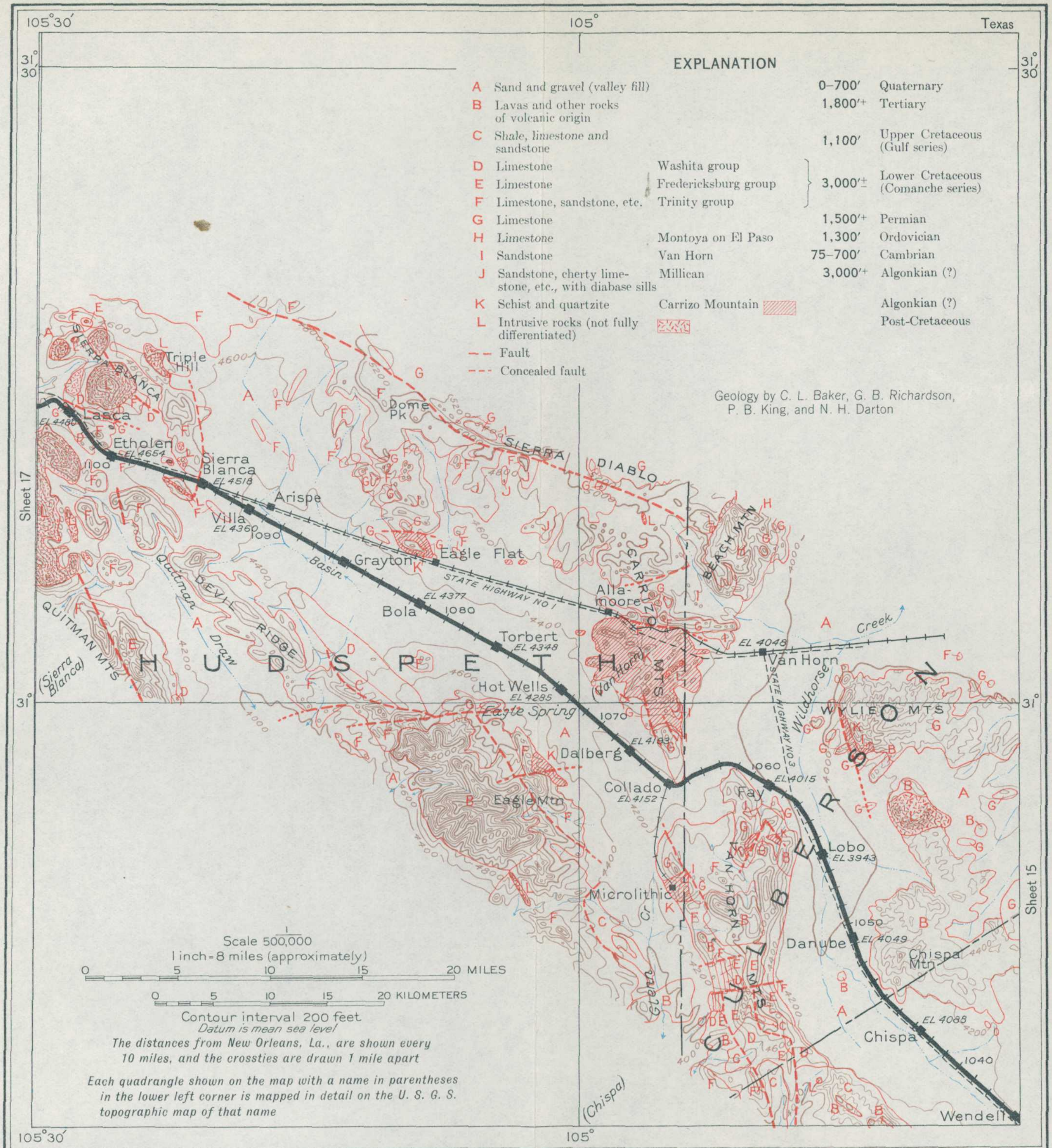
Elevation 4,754 feet.
Population 28.*
New Orleans 1,100 miles.

Near Etholen siding there are many interesting geologic features. Not far north is the huge cone of the Sierra Blanca, rising nearly 2,200 feet above the adjoining valley. Near its south slope passes a west-northwest fault, on the south or upthrown side of which limestone of Permian age abuts against strata of the Washita group, which constitute the platform on which the mass of Sierra Blanca rises. In the gap on the north side of the peak a large variety of interesting fossils have been found in these strata.

The Quitman Mountains are very conspicuous southwest of the railroad near Etholen. They consist of a mass of intrusive granite at the north and south ends and a huge central intrusion of quartz syenite. These rocks are cut by dikes of diabase and augite porphyry. The granite and syenite intrusions have lifted and deformed the Cretaceous strata over an area of considerable extent. A most interesting example of the alteration of sedimentary rocks by an igneous intrusive mass is presented on the north side of the Quitman Mountains 5 miles south-southwest of Etholen siding. Here part of the limestone (Finlay) has been changed to marble by the heat of the intrusive quartz syenite, and a great zone of garnet (grossularite) has been developed at the contact. There is also considerable vesuvianite and actinolite. Sandy beds are altered to hornfels, and much silica has been deposited, together with iron, manganese, copper, zinc, and silver minerals. Many of these minerals are incrusted with chalcedony. The principal materials added to the sedimentary rocks are silica and iron oxide, much of the latter in the form of hematite. There are many mineral deposits in the altered rocks near the Quitman Mountains which have been extensively prospected but have not yet developed economic importance. Besides iron, lead, copper, and silver, small amounts of nickel, tungsten, uranium, gold, and molybdenum have been reported.

In the small ridge west of Etholen are limestones and shales of upper Washita age (probably Del Rio) carrying "*Nodosaria*" *texana*. Southwest of the siding is a high rough ridge of a syenitic intrusive rock that also constitutes the north end of the Quitman Mountains, just beyond. In these ranges are the Bonanza and Alice Ray mines, formerly productive. Nearly all the surfaces in this general region are bare and rocky, and the vegetation has the wide spacing characteristic of arid regions. In the valleys and on gentler slopes, however, there is considerable grass and other forage for stock.

The knobs just northwest of Etholen consist of a conglomerate (probably the same as the Campagrande formation of Richardson, the


Texas
EXPLANATION
A Sand and gravel (valley fill) 0–700′ Quaternary
B Lavas and other rocks of volcanic origin 1,800′+ Tertiary
C Shale, limestone and sandstone 1,100′ Upper Cretaceous (Gulf series)
D Limestone Washita group
E Limestone Fredericksburg group
F Limestone, sandstone, etc. Trinity group
3,000′± Lower Cretaceous (Comanche series)
G Limestone 1,500′+ Permian
H Limestone Montoya on El Paso 1,300′ Ordovician
I Sandstone Van Horn 75–700′ Cambrian
J Sandstone, cherty limestone, etc., with diabase sills Millican 3,000′+ Algonkian (?)
K Schist and quartzite Carrizo Mountain Algonkian (?)
L Intrusive rocks (not fully differentiated) Post-Cretaceous
Fault
Concealed fault
Geology by C. L. Baker, G. B. Richardson, P. B. King, and N. H. Darton
105°30′
105°
31° 30′
31°
Sheet 17
Sheet 15
HUDSPETH
CULBERSON
SIERRA BLANCA
Triple Hill
Lasca
Etholen
Sierra Blanca
Arispe
Villa
Grayton
Eagle Flat
STATE HIGHWAY NO 1
Bola
Torbert
Hot Wells
Eagle Spring
Dalberg
Collado
Allamoore
Dome Pk
SIERRA DIABLO
BEACH MTN
CARRIZO MTS
Van Horn
Creek
Wildhorse
STATE HIGHWAY NO 3
WYLIE MTS
Fay
Lobo
Danube
Chispa Mtn
Chispa
Wendell
Microlithic
Eagle Mtn
QUITMAN MTS
Quitman Draw
DEVIL RIDGE
Basin
VAN HORN MTS
(Sierra Blanca)
(Van Horn)
(Chispa)
Scale 1/500,000
1 inch = 8 miles (approximately)
0 5 10 15 20 MILES
0 5 10 15 20 KILOMETERS
Contour interval 200 feet
Datum is mean sea level
The distances from New Orleans, La., are shown every 10 miles, and the crossties are drawn 1 mile apart
Each quadrangle shown on the map with a name in parentheses in the lower left corner is mapped in detail on the U. S. G. S. topographic map of that name

basal formation of the Comanche series), and this rock also occurs in near-by hills south of the railroad, in the small hill three-quarters of a mile east of the siding, and at some other localities in the same general region. It consists of coarse sandstone and conglomerate of brown color and represents an old beach or river deposit. Underlying limestone of Permian age appears on the north side of the hills 2 miles north of Etholen, but the contact is covered by talus. (Turn to sheet 17.)

Etholen is near the divide between the elevated basin that lies east of Sierra Blanca and the deep valley which has been excavated by the Rio Grande. To the northwest of this divide the railroad descends a steep grade past Lasca and Torcer sidings. In this vicinity the railroad crosses the old "salt trail" from the Indian villages on the Rio Grande to the great salt flats 45 miles northeast of Sierra Blanca, which were an important source of supply for many years and the cause of bitter controversy and hostilities.

At Torcer the road begins a very tortuous course to distribute the grade, and there are many curves, one of which is shaped like a huge horseshoe. These are along the east slope of the Malone Mountains, and in places the railroad touches the hard rocks of that range, but most of the descent is in valley fill, which is 600 feet or more thick. The descent to Small siding is about 550 feet in a distance of 12 miles. In this descent there are good views of the Malone Mountains, to the southwest, and the Finlay Mountains, to the northwest. The Finlay Mountains consist of a dome-shaped uplift of the strata, truncated at the top, so that a considerable area of underlying limestone and shale of Permian age is exposed. The surrounding ridges consist of sandstones and limestones of the Trinity group (Comanche series), of which about 800 feet is exposed. These strata are intruded by igneous rocks at several places.

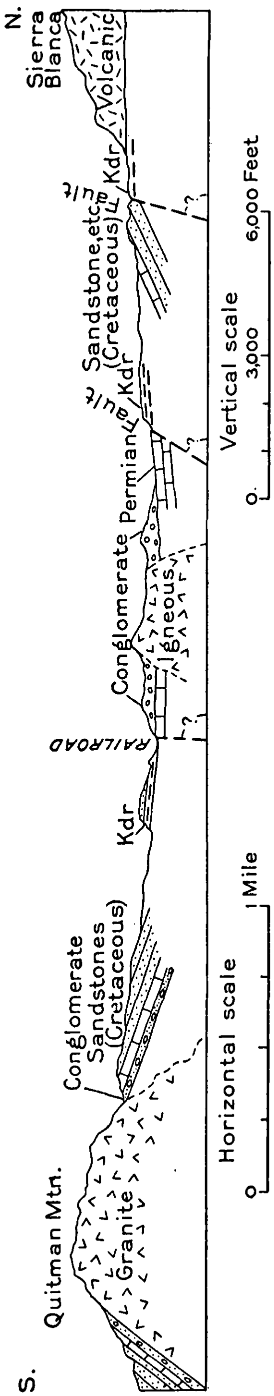


FIGURE 23.—Section from the north end of the Quitman Mountains to the east slope of the Sierra Blanca, Tex., crossing the railroad just west of Etholen station. After C. L. Baker. Kdr, Del Rio formation (Cretaceous)

From Small siding the railroad proceeds west down a small valley cut deeply in pink loams or sandy clays; these appear to have been deposited in a lake that once occupied the area, probably caused by the damming of the Rio Grande temporarily by some earth movement. About 1½ miles beyond Small and at intervals to Finlay there are fine views of the Malone Mountains[84] showing sharply flexed limestones of Jurassic age. The most noticeable feature is a syncline or trough, which is clearly discernible from the train, as shown in Plate 17, *B*.

Flexing and faulting have brought Permian gypsum to the surface along the railroad halfway between mileposts 756 and 757, where it is extensively quarried for use as plaster of paris.[85] The quarry is south of the tracks. Near the quarry the gypsum is overlain by 200 feet of conglomerate and light-brown conglomeratic sandstone, which is overlain by limestone interbedded with sandstone, the latter in part conglomeratic. Certain fossils at this horizon are believed by Baker to indicate Cretaceous age but earlier than any Trinity elsewhere in Texas. The gypsum is known to be of Permian age because an overlying limestone, exposed half a mile east of Torcer siding, carries the characteristic fossil *Richthofenia*. Next above this are Jurassic beds.

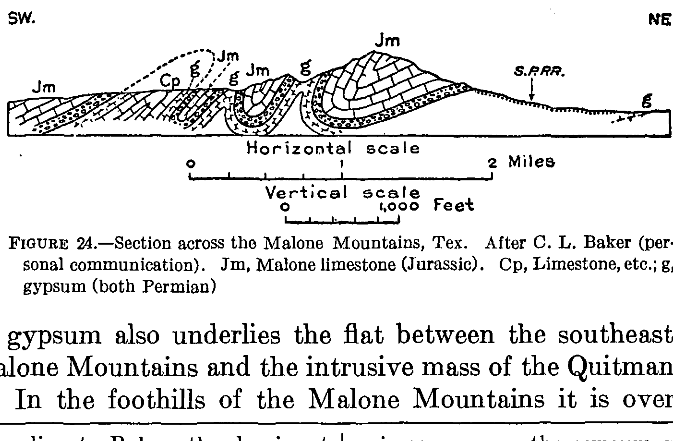


FIGURE 24.—Section across the Malone Mountains, Tex. After C. L. Baker (personal communication). Jm, Malone limestone (Jurassic). Cp, Limestone, etc.; g, gypsum (both Permian)

The gypsum also underlies the flat between the southeast end of the Malone Mountains and the intrusive mass of the Quitman Mountains. In the foothills of the Malone Mountains it is overlain by

[84] According to Baker, the dominant structure in these mountains is a syncline overturned on its southwestern flank, a feature which is conspicuous from afar along the summit of the main ridge. The valley southwest of this ridge follows the axis of an anticline overturned to the northeast and so truncated by erosion as to expose the gypsum (Permian) that lies not far below the base of the Malone formation. The northwestern part of the mountain mass on the southwest side of this overturned syncline is anticlinal in structure, with the axis pitching southeastward. The main anticlinal axis passes near the gypsum quarry on the railroad. On the southeast side of the syncline there is an overthrust to the northeast. There is much minor crumpling on the southeast end of the main northeastern ridge. The general features are shown in Figure 24.

[85] Gypsum consists of calcium sulphate with about 20 per cent of combined water. Plaster of paris, which is used extensively in the arts, is made from it by "cooking" the gypsum at a moderately high temperature to drive off part of the combined water and grinding the resulting mass to fine powder.

conglomerate (basal Malone) of limestone and chert, including boulders as much as 8 inches in diameter, one of which yielded remains of *Fusulina elongata,* a fossil of Permian age. These boulders were of course derived from the underlying strata. This basal conglomerate is overlain by limestone containing conglomerate and brown sandstone layers, all of Jurassic age (Malone formation). On the east side of this area the gypsum is apparently overlain by brown sandstone and blue limestone of the Malone formation, dipping southwest.[86]

West of the gypsum quarry the railroad ascends a low ridge from which there are fine views of the Finlay Mountains, to the north, and of the Sierra del Presidio, far to the south in Mexico; the latter is more closely approached after the descent is made into the valley of the Rio Grande.

Finlay is a small settlement on the high alluvial plain northwest of the Malone Mountains. Near by are several small knobs of limestone, some of them Jurassic, and some Cretaceous (Finlay), with members of conglomeratic sandstone. About 12 miles due south, near the Rio Grande, are the ruins of Fort Quitman, once an important army post when the Indians were on the warpath.

Finlay.

Elevation 3,951 feet.
Population 60.*
New Orleans 1,118 miles.

West of Finlay there is another long tortuous descent of nearly 400 feet into the valley of the Rio Grande. There are many cuts in lake beds, in most places eroded into badland forms, notably at points 2 miles beyond Finlay, at Stevenson siding, and thence to Madden and beyond. The material is a pink sandy clay of compact texture, with a few harder sandy beds. Badlands such as are shown in Plate 17, *A,* result from rapid gullying in soft beds that are sufficiently compact to sustain steep slopes. In the next 5 miles the valley of the Rio Grande is reached, and the railroad curves to a northwest course, which continues for 60 miles to El Paso.

The uplifts that followed the time of great volcanic activity in western Texas strongly affected the preexisting drainage, forming basins between the mountain blocks, some of which still exist. A wide trough excavated by the Rio Grande was dammed by the uplifts

[86] The Jurassic rocks of the Malone Mountains (Malone formation) consist of blue and gray limestones with a few intercalated layers of conglomerate and sandstone, having a thickness of about 1,000 feet. At the base is a conglomerate member, in places 50 feet thick, containing many limestone boulders. Some of the strata contain molluscan fossils of Jurassic age. The fossils are most abundant, so far as reported, in low, detached hills about 2 miles east of Torcer siding at a horizon believed to be about 300 feet above the base of the formation. The intricate folding and complex faulting in these mountains renders it difficult to determine the thickness and succession of the rocks. Owing to overturning of the folds some of the older beds lie on younger ones; this is likewise the case with the Cretaceous strata in the Quitman Mountains, to the southeast. Some of the most distinctive fossils found in the Malone formation are ammonites and gastropods in considerable variety, but there are also many other forms. (Described by Cragin.)

in the Big Bend region, causing a lake or series of lakes extending up the valley to the mountains at El Paso. In these waters were deposited a thick mass of fine-grained sediments, in large part of flesh color, orange-brown, and pale grayish green. Some beds are sandy, and thin sandstone layers are included; where these deposits are near the mountain slopes much coarse material is present. The lake beds were capped by stream deposits, which now fill many old gaps and extend over moderately high divides. North of Fort Bliss holes 2,300 feet deep have failed to reach the base of the valley fill.

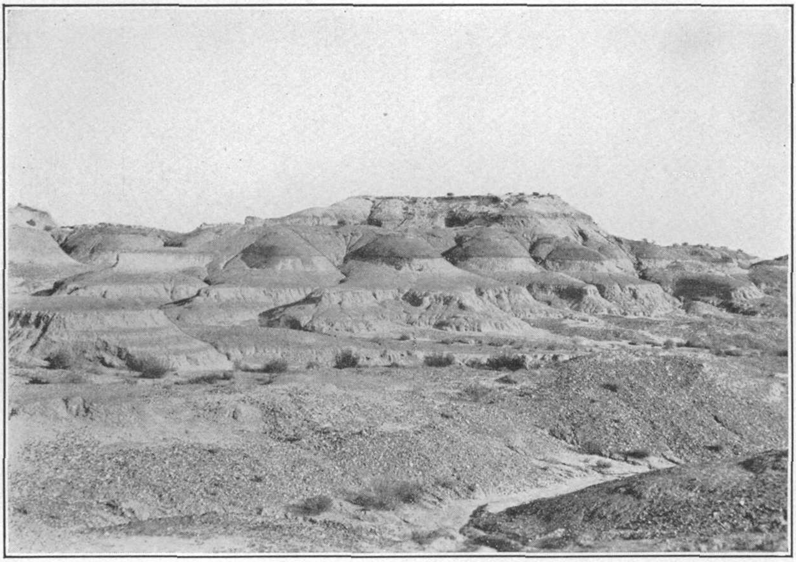
The lacustrine condition in the Rio Grande Basin was terminated by the deepening of the outlet; this finally tapped off the water, and then, as canyons were cut through the ridges, a deep valley was developed. As the process continued, the side streams and arroyos cut deeply into the alluvial capping and the underlying lake deposits, and in the main valley terraces and a wide alluvial flat were developed.

McNary.

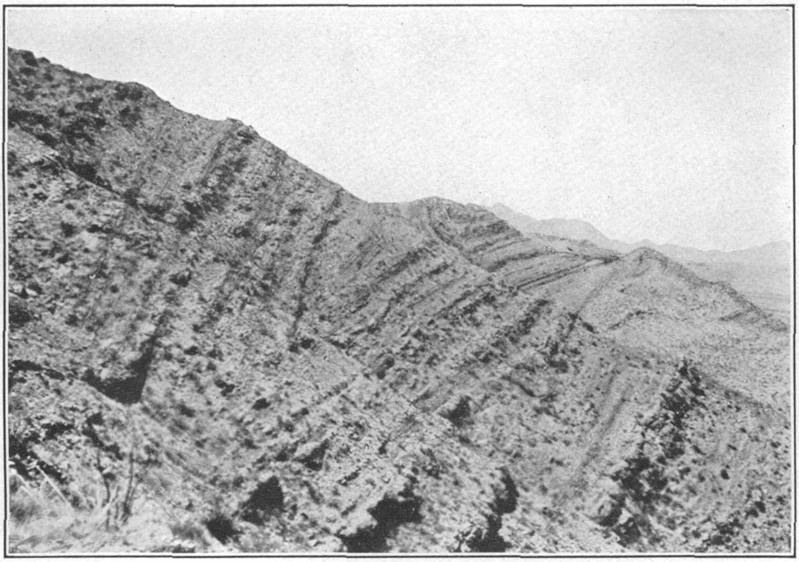
Elevation 3,571 feet.
Population 50.*
New Orleans 1,131 miles.

McNary, formerly known as Nulo, has developed into a small town for local trade in the irrigated district along the Rio Grande. This valley, with rich bottom-land soils, mild climate, wide areas of level surface, and a large water supply from the river now controlled by the Elephant Butte Reservoir, has developed rapidly in recent years. Much of the land from McNary to El Paso is under irrigation and is yielding large crops of cotton, alfalfa[87] and other forage plants, grain, fruits, and vegetables. The railroad passes near or through cultivated fields for the entire route, in striking contrast to the sand hills and barren lands of the area above the ditches. The alfalfa fields are usually of a rich green color, which becomes shaded with the lavender of the sweet-smelling blossoms when the plant is left to continue its growth for the development of seed. In 1929 the irrigated area in Hudspeth County was about 14,000 acres and in El

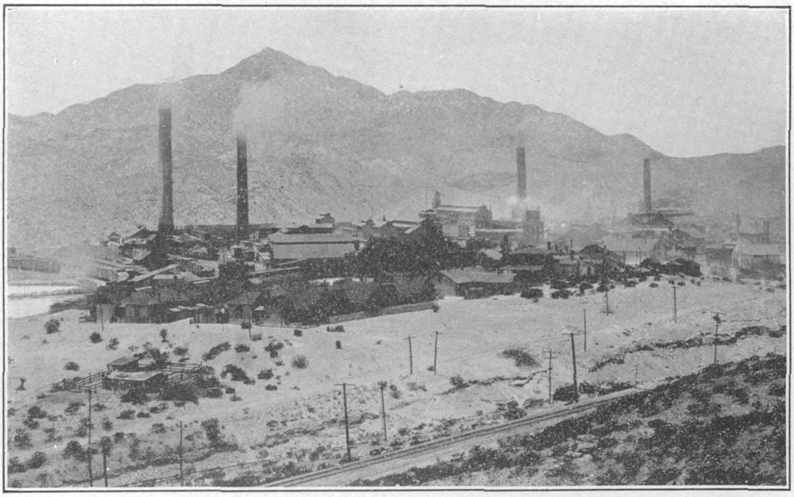
[87] Alfalfa (lucern in Europe) has long been cultivated as forage, for historians record its introduction into Greece from Persia as early as the fifth century before Christ. Its cultivation was attempted by early colonists in America, but not until 1854, when a variety from Chile was introduced into California, did its development proceed rapidly. Alfalfa is best adapted to semiarid regions, for it does not require a moist climate and does not suffer from extreme heat or from relatively severe cold. It thrives best under irrigation, an occasional flooding being necessary for its growth. It has been found by the Arizona Agricultural Experiment Station that 600 gallons of water is required to raise 1 pound of alfalfa. Besides being highly nutritive and palatable, alfalfa, when well rooted, is of rank growth, long lived, and hardy. Some fields are 25 years old, but on most soils the best yields are obtained in the third to seventh years. The roots range from 6 to 15 feet in length. Though alfalfa fields can be started in some places with a pound of seed (about 220,000 seeds) to the acre, about 15 pounds is used on irrigated lands. In places alfalfa is cut three to five times a year and therefore produces a larger yield than any other forage plant in the western United States. In some localities the plant is allowed to ripen in order to develop the seed, which is in considerable demand.



A. BADLANDS IN LAKE BEDS IN VALLEY OF RIO GRANDE WEST OF FINLAY, TEX.
(P. B. King.)

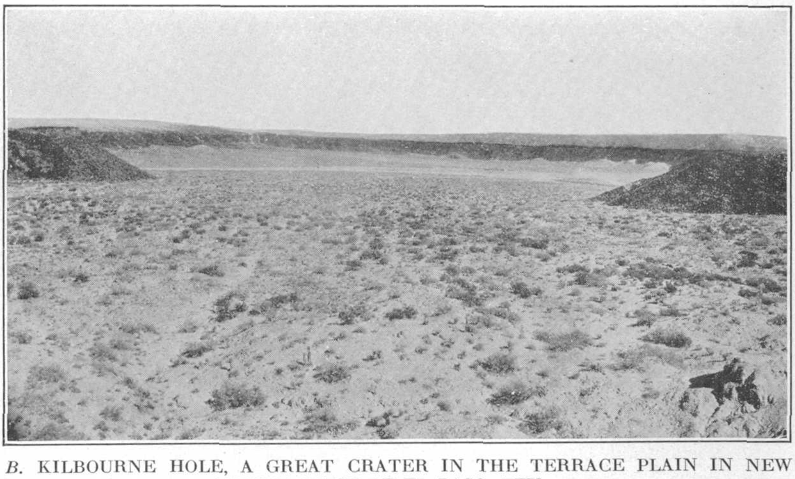


B. OVERTURNED SYNCLINE OF MALONE MOUNTAINS, TEX.
Looking southeast. (P. B. King.)



A. SMELTER AT EL PASO, TEX.

Receives large amounts of gold, silver, copper, and other ores mined in the Southwest. The mountains in the background are in Mexico.



B. KILBOURNE HOLE, A GREAT CRATER IN THE TERRACE PLAIN IN NEW MEXICO WEST OF EL PASO, TEX.

Believed to be a result of steam explosion. Looking south. There is a ranch near center of hole.

Paso County 65,442 acres, an increase in the two counties of two and one-fourth times in 10 years. From McNary northwestward the railroad skirts the foot of the steep slope demarking the higher terrace. To the southwest are wide areas of irrigated lands, and across the river to the south are fine views of the high and picturesque front of the Sierra del Presidio, in Mexico. It consists of strata of Comanche age. A mile west of McNary is the 5,000-acre cotton plantation named "Algodones" (ahl-go-do'nace, from Spanish algodón, cotton), on which most of the water is pumped from shallow wells by electric power.

Among the many frontier military posts established by the Government the garrison at Fort Hancock was regarded as one of the most important, for it guarded the San Antonio mail road through the Rio Grande Valley below El Paso as far as Fort Quitman, 20 miles away. The ruins of some of the old buildings are still visible a short distance from the tracks about half a mile west of the station.

Fort Hancock.

Elevation 3,595 feet.
Population 120.*
New Orleans 1,136 miles.

In this part of the valley the railroad passes along the edge of the sand hills at the foot of the terrace that rims the valley. This terrace,

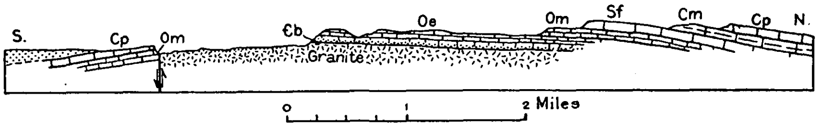


FIGURE 25.—Section through the south end of the Hueco Mountains, 20 miles north-northeast of Fabens, Tex. Cp, Limestone (Permian); Cm, limestone (Pennsylvanian and Mississippian); Sf, Fusselman limestone; Om, Montoya limestone; Oe, El Paso limestone; Ꞓb, Bliss sandstone

which consists of sand and gravel, slopes upward to the foot of the high plateau extending northwest from the Finlay Mountains. This plateau is capped by the Finlay limestone, dipping to the southeast at a very low angle. At one point 8 miles northwest of Fort Hancock a butte of shale of Trinity age protrudes through the terrace deposits. The wide terraces adjoining the Rio Grande in this region consist largely of lake deposits laid down when the river was blocked for a period (p. 120) and detritus washed from the ridges to the north. Some of the material is loose sand, and in many areas this has been blown by the wind into sand dunes.

Northwestward from Fort Hancock the railroad follows the edge of the sand hills past Ross, Iser, and Polvo sidings. Not far west are extensive fields of cotton, alfalfa, and other crops raised by irrigation, partly by water pumped from the valley fill.

The course of the Rio Grande is very sinuous, and some of the larger bends bring it near the railroad. On the opposite side in Mexico are irrigated areas and in places large mountains, which seem close. There are many cottonwood trees along the valley, and for a while in the summer the air is filled with their seeds wafted by fluffy tufts of cotton.

Tornillo.

Elevation 3,586 feet.
Population 60.*
New Orleans 1,153 miles.

Tornillo [88] (tore-nee′yo) is a small village sustained by cotton raising and other agricultural interests. Fabens, 6 miles beyond it, is a town of considerable importance in the center of a large and prosperous irrigation community.

Fabens.

Elevation 3,620 feet.
Population 1,623.
New Orleans 1,159 miles.

The contrast here is very great between the sand-hill and desert country of the terrace just north and the fertile irrigated district in the bottom lands.

About 20 miles north of Fabens, in places visible from the railroad, is the south end of the Hueco Mountains (way′co).[89]

Clint.

Elevation 3,635 feet.
Population 70.*
New Orleans 1,166 miles.

Clint is a local center for a productive irrigation district which extends to and beyond El Paso. In this district the railroad passes through irrigated fields of alfalfa and many other crops, gardens, and orchards. One of the large ditches here parallels the railroad for several miles. Most of the roads in this district are "alamedas" (ah-lah-may′das) embowered by overarching cottonwood trees.

In this portion of the valley a few hundred Indians still remain, mostly working on ranches or associated with Mexican settlements. Originally they had many rancherías of their own. They were of the Pueblo type and known as the Tiguas (Teguas or Turcervas). Of the many Indians formerly in Texas probably not more than 2,100 remain, widely scattered in small groups, the largest of which is in Polk County, in the east-central part of the State.

The old Mexican village of San Elizario, 2 miles west of Clint, was once the seat of Spanish government of the territory of Nuevo Méjico. The viceregal residence is still standing opposite the old church and jail. The place is famous also as the center of the "salt

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[88] This name is used for a "screw bean" plant (*Strombocarpa pubescens*), common in the alluvial valleys of this region. The plant is similar to mesquite but bears a twisted bean that contains considerable sugar.

[89] This range presents a succession of strata from Permian limestone at the top through limestones of Pennsylvanian and Mississippian age, Silurian (Fusselman limestone), Ordovician (Montoya and El Paso limestones), and Upper Cambrian (Bliss sandstone). A coarse pink granite crops out in places, apparently underlying the Bliss sandstone. In the south edge of the area the limestone of Permian age lies directly on Montoya limestone. A typical section is shown in Figure 25. Farther north, in the western portion of the mountains, there are extensive exposures of Carboniferous, Silurian, and Ordovician strata. Here in places the Permian has a red conglomeratic member at the base lying unconformably on limestones of Pennsylvanian age. These relations are well exposed in Powwow Canyon on the highway from El Paso to Carlsbad. The lower beds of the limestones regarded as Permian carry abundant remains of the foraminifer *Schwagerina uddeni*,

war" of 1877, initiated by the earlier settlers, who rebelled at paying for salt in Salt Flat (see p. 117), and also as the scene of some of the exploits of the outlaw known as "Billy the Kid."

Ysleta.
Elevation 3,670 feet.
Population 2,025.*
New Orleans 1,175 miles.

Ysleta (ees-lay'ta) is one of the old settlements of the Rio Grande Valley, now largely Mexican in population but originally Indian. Its cathedral is the old Spanish mission of Nuestra Señora de Carmen, founded in 1682 shortly after the Indian rebellion of 1680.

From Ysleta into El Paso there is a wide zone of almost continuous settlement with attractive residences, shade trees, and irrigated fields, gardens, and orchards raising hay, alfalfa, and other forage crops, vegetables, fruits, and other products for the local market and for shipment. Long-staple cotton is also an important crop here, yielding a bale to the acre. After the long trip through the thinly populated arid part of western Texas this irrigated valley seems like a different country. About 180,000 acres is under cultivation above and below El Paso. With an average annual rainfall of only 9 or 10 inches irrigation is absolutely necessary. The water is taken from the river, which has furnished it for several centuries, but now the Elephant Butte Reservoir, 115 miles above El Paso, insures a regular and larger supply.

Near El Paso there are fine views of the Franklin Mountains, to the northwest, and some prominent ranges in Mexico, to the west and southwest.

El Paso.
Elevation 3,725 feet.
Population 102,421.
New Orleans 1,188 miles.

The railroad enters El Paso from the southeast and goes to a union station near the western edge of the city. El Paso is a large, long-established business, livestock, and railroad center, an important port of entry from Mexico, and the headquarters of the large Army post of Fort Bliss. Its original site was determined by the gateway cut by the Rio Grande and a good ford crossing into Mexico. It is on "El Camino Real" (ca-mee'no ray-ahl'), now Highway 85, the oldest highway on the continent, which passes through the city as San Francisco Street.

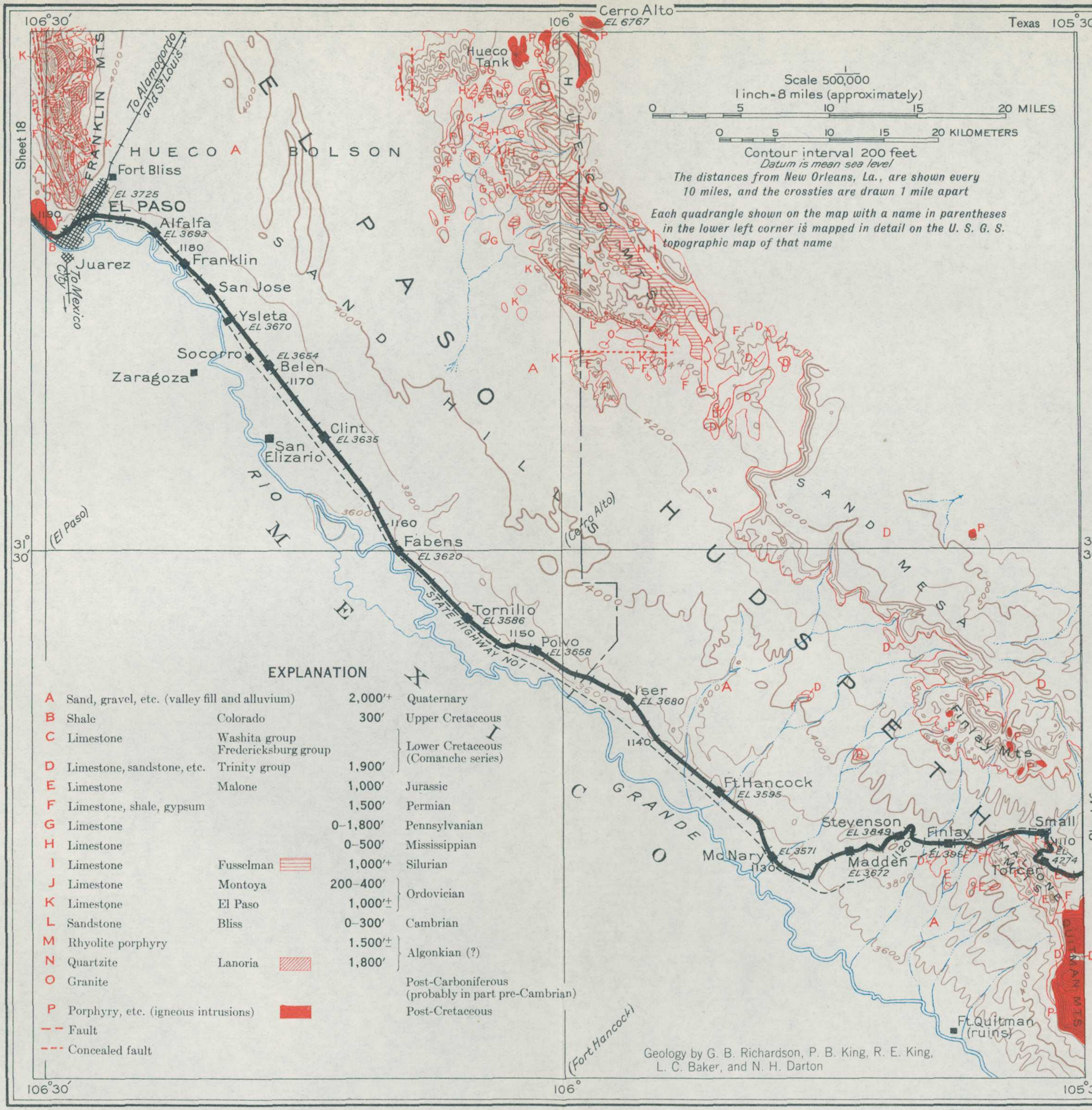
The Rio Grande was discovered in 1536 by Cabeza de Vaca, who, after eight years' wanderings following the disastrous failure of the Narváez expedition to Florida, forded the river just above its junction with the Rio Conchos, 100 miles below El Paso. It seems probable that De Vaca reached the El Paso region in 1536 and traveled up its east side far north into the present New Mexico before turning southwest to reach Culiacán, in Mexico. (Sauer, Bolton, and R. T. Hill.) It was next visited in 1540, in its northern extension, by Hernando de Alvarado, one of Coronado's captains, who named it the Rio Bravo del Norte, a name still in use on most Mexican maps.

The first explorers to cross the ford at El Paso were Francisco Sánchez Chamuscado with Padre Agustín Rodríguez in 1581, and

Antonio de Espejo the next year. They had both ascended the Rio Grande, which they called the Guadalquivir (gwa-dal-kee-veer′), from the mouth of the Rio Conchos. In 1598 Juan de Oñate reached the Rio Grande 25 miles below El Paso with a band of heroic colonists consisting of 130 soldiers or more, most of them with their families, with 83 wagons and 7,000 cattle. This expedition crossed the river at El Paso and took possession of all the region to the north in the name of King Philip II of Spain, calling it Nuevo Méjico. Oñate then ascended the Rio Grande Valley to the mouth of the Rio Chama, in New Mexico, where his colony was established under the name of San Juan de los Caballeros. The headquarters of this Spanish colony was subsequently removed to Santa Fe, and it was from that place, at the time of the pueblo rebellion in 1680, that about 1,000 settlers and some loyal Indians fled down the valley to the mission of Nuestra Señora de Guadalupe, started by the Franciscans in 1659 on the south side of the river, at the present Ciudad Juárez (seeyou-dahd′ hwah′race).[90] This incident led to the establishing of a presidio (fort) and supply station at the mission, which was the beginning of settlement in the general El Paso region. Twelve years after the revolt Diego de Vargas left El Paso and effected an easy reconquest of the Pueblo Indians.

In 1700 the settlement at the ford had a population of 5,000, including 637 Indians, and the white inhabitants of the whole territory numbered perhaps 19,000 and the Indians 10,000. The place had a large traffic, especially in January, when an annual fair held in Chihuahua was attended by New Mexican traders, at times numbering 500. The neighborhood was famous for its orchards and vineyards, supported by irrigation from a dam, which was usually destroyed by each summer's floods. Zebulon Pike was the first English-speaking person to visit the place, having been taken there in 1807 as a prisoner by Spanish forces. At this time there was no settlement on the north side of the river, but the sites of the Mills Building and the Southern Pacific station in El Paso were occupied by the adobe buildings of the hacienda of a Mexican named Ponce de León. On his death in 1857 it came into American hands, the first owner being Franklin Coontze, after whom Mount Franklin is named. About that time James Magoffin, whose diplomacy had secured for the United States the acquisition of New Mexico from Mexico without the firing of a single shot, established a trading post near by which was called Magoffinsville. Fort Bliss, a short distance northeast, was started by the United States Government in 1848 for the protection of the frontier. The region was generally referred to as El Paso (the pass).

[90] Named for the liberator Benito Juárez, first President of Mexico, who at one time had the capital there


Cerro Alto
EL 6767
106°30′
106°
Texas 105°30′
Hueco Tank
Scale 1/500,000
1 inch = 8 miles (approximately)
0 5 10 15 20 MILES
0 5 10 15 20 KILOMETERS
Contour interval 200 feet
Datum is mean sea level
The distances from New Orleans, La., are shown every 10 miles, and the crossties are drawn 1 mile apart
Each quadrangle shown on the map with a name in parentheses in the lower left corner is mapped in detail on the U. S. G. S. topographic map of that name
Sheet 18
FRANKLIN MTS
To Alamogordo and St. Louis
HUECO BOLSON
Fort Bliss
EL 3725
EL PASO
1190
Alfalfa
EL 3693
1180
Franklin
Juarez
To Mexico City
San Jose
Ysleta
EL 3670
Socorro
EL 3654
Belen
1170
Zaragoza
Clint
EL 3635
San Elizario
EL PASO SAND HILLS
HUECO MTS
RIO GRANDE
MEXICO
1160
Fabens
EL 3620
(El Paso)
31° 30′
(Cerro Alto)
Tornillo
EL 3586
1150
Polvo
EL 3658
STATE HIGHWAY NO1
Iser
EL 3680
1140
Ft. Hancock
EL 3595
HUDSPETH
SAND MESA
Finlay Mts
Stevenson
EL 3849
Finlay
Small
Sheet 16
McNary
EL 3571
1130
Madden
EL 3672
1120
Torcer
1110
EL 4274
MALONE MTS
QUITMAN MTS
Ft. Quitman (ruins)
(Fort Hancock)
Geology by G. B. Richardson, P. B. King, R. E. King, L. C. Baker, and N. H. Darton
106°30′
106°
105°30′
EXPLANATION
A Sand, gravel, etc. (valley fill and alluvium) 2,000′+ Quaternary
B Shale Colorado 300′ Upper Cretaceous
C Limestone Washita group Fredericksburg group
D Limestone, sandstone, etc. Trinity group 1,900′
Lower Cretaceous (Comanche series)
E Limestone Malone 1,000′ Jurassic
F Limestone, shale, gypsum 1,500′ Permian
G Limestone 0–1,800′ Pennsylvanian
H Limestone 0–500′ Mississippian
I Limestone Fusselman 1,000′+ Silurian
J Limestone Montoya 200–400′
K Limestone El Paso 1,000′±
Ordovician
L Sandstone Bliss 0–300′ Cambrian
M Rhyolite porphyry 1,500′±
N Quartzite Lanoria 1,800′
Algonkian (?)
O Granite Post-Carboniferous (probably in part pre-Cambrian)
P Porphyry, etc. (igneous intrusions) Post-Cretaceous
Fault
Concealed fault

In 1852 a post office, called Franklin, was established here, and in 1859 this name was changed to El Paso. There was no town development until after the Civil War—in fact, there was no settlement between Fort Clark and the El Paso region, a distance of 480 miles. There was continuous traffic, however. Three mail routes afforded communication with Santa Fe, San Antonio, and San Diego (see p. 97), and San Francisco. From 1858 to 1861 the Butterfield Overland Mail transported mail semi-weekly from St. Louis and Memphis to San Francisco under contract at $600,000 a year. The annual receipts reported from this line in 1859 were $27,230. The railroad was used to Tipton, Mo., and stage coaches the rest of the way. The time consumed was 21 to 23 days, and the passenger fare was $150 and $200, without meals. This mail service was transferred to a more northerly route in 1861, and soon after that the Civil War cut the seceded States off from the United States postal service. A few years after hostilities ceased a triweekly schedule was established for this region. The railroad reached El Paso from the east in 1883 and in the next few years brought many immigrants to the Rio Grande Valley. Since that time the city has had a rapid growth.

El Paso has long been prominent as a headquarters for the mining industry, although there are no notable mines in its immediate vicinity. For many years it has had the largest custom smelter in the United States, usually employing 1,000 men and treating ore from New Mexico, Arizona, and Texas. (See pl. 18, *A*.) In 1930 the Nichols copper refinery was completed on the eastern edge of the city. Just west of this refinery are the Pasotex and Texas Co. oil refineries, which receive crude oil by a long pipe line from the Winkle field in Texas. Another pipe line brings gas to El Paso. The large cement plant on the western edge of the city furnished the cement for the Elephant Butte Dam; it utilizes the limestone of the Comanche series.[91] Beaumont Hospital is a large Government establishment for tubercular soldiers, and Fort Bliss, 5 miles northeast of the center of the city, with 153 officers and 2,362 men (in 1930), is the largest cavalry post in the United States. The Texas College of Mines, a branch of the University of Texas, and Loretto College or convent are also in El Paso. The city water supply is obtained from a group of deep wells, which are reported to yield 14,000,000 gallons a day.

[91] Cement is made by roasting a mixture of ground limestone and shale and grinding the resulting "clinker" to a fine powder. In some places clay is used instead of shale. Some limestones contain naturally a suitable admixture of the clay element for the manufacture of hydraulic cement. Most limestones could be utilized for cement manufacture, but there is a limit to the demand, and it is difficult to introduce a new brand of cement in competition with cements of established reputation which have proved their uniformity and reliability by many tests. The items of cheap fuel and local market are important considerations in making cement.

The climate at El Paso is typical of that in much of trans-Pecos Texas. The mean annual precipitation is slightly less than 10 inches, with a recorded range from 2.22 to 18 inches. Most of the rain falls in heavy local showers, and more than half of the annual total comes in July, August, and September. The greatest recorded fall was on July 9, 1881; it amounted to 6½ inches. The mean annual temperature is 63.5°, and the mean monthly minimum about 31° in January. The temperature is rarely below 20° and then only for a few hours. The average humidity ranges from 23.2 per cent in May to 47.3 per cent in January, with an average of 39 per cent for the year. The annual evaporation is estimated at 82 inches. Snow falls rarely and then only in small amount, and usually it melts in a few hours. The percentage of sunshine is about 81.

Outside of the irrigated zone the vegetation is characteristic of an arid climate. Trees are rare, even on the mountains, but there is a scattered growth of mesquite and creosote bush (*Covillea*). Yucca, lechuguilla, sotol, bear grass, ocotillo, and several species of cactus are abundant on the slopes.

In New Mexico and Texas above El Paso the Rio Grande flows in a wide valley of alluvium, bordered by a high older terrace plain; in parts of its course farther north in New Mexico it is in deep rocky canyons. At El Paso the valley is constricted to the narrow rock-walled pass that gives name to the city, but the bordering high terrace continues far down the valley. Below the pass the alluvial plain is a broad flat in which the river meanders widely, often changing its course by cutting new channels at times of freshets. The high terrace plain that borders this valley terminates in bluffs and steep slopes, in places 200 feet high above the bottom lands. The smooth plain at the top of these bluffs extends far north as a wide bolson or desert flat between mountain ranges. Near El Paso there are several distinct benches, 3,800 to 3,950 feet above sea level, mostly in the form of mesas or projections from the base of the Franklin Mountains. These benches slope gently toward the river and are in part capped by caliche, an infiltration of calcium carbonate in the sand, which makes a material so hard that it helps to preserve the tabular form and sharp edges of the mesas. The Franklin Mountains form a high ridge on the southern prolongation of an axis of uplift which extends across central New Mexico from the Rocky Mountains. Probably this uplift is cut off to the south by a fault. The range rises abruptly about 3,000 feet above the adjoining plains or valleys and culminates in Mount Franklin (elevation 7,152 feet). The west side is mainly a dip slope of heavy beds of limestone with pronounced westerly dip; the east side shows many ridges, irregular lower crests, and buttes, deeply cut by canyons. The range is a typical tilted block of the basin-range type, which predominates in a large part of the Southwest.[92]

The huge "M" so conspicuous on the mountain side is painted each year by the students of the School of Mines; the "E" is placed there by high-school students. At night a flashing beacon to guide airplanes

[92] The Franklin Mountains present a fine succession of strata from pre-Cambrian to Permian, all so bare and free from talus that the various formations are easily studied. They have been described by Richardson. The section in Figure 26 shows the principal features of the range, and the formations are listed in the following table:

Formations exposed in the Franklin Mountain area

Age	Formation		Thickness (feet)
Lower Cretaceous (Comanche).		Limestone, shale, and sandstone.	300
Permian.	Hueco.	Limestone.	1,500
Pennsylvanian.	Magdalena.	Limestone.	0–100
Devonian.	Percha.	Limestone, dark, impure.	40
Silurian.	Fusselman.	Limestone, massive, light and dark.	1,000
Ordovician.	Montoya.	Limestone, massive, magnesian.	20–400
	El Paso.	Limestone, gray, largely slabby; weathers light.	1,000±
Cambrian.	Bliss.	Sandstone, brown and gray, locally conglomeratic at base.	
Algonkian(?).		Rhyolite porphyry, mostly red, with agglomerate at base.	1,500±
	Lanoria.	Quartzite, light and dark, cut by diabase dikes and sills.	1,800+

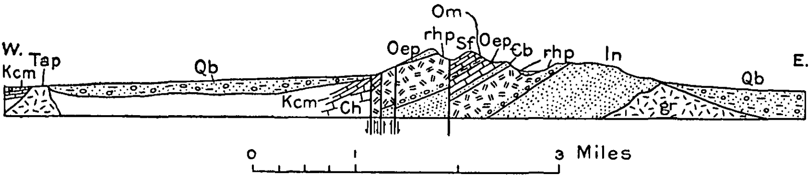


FIGURE 26.—Section across the Franklin Mountains north of El Paso, Tex. After Richardson. In, Lanoria quartzite; rhp, rhyolite porphyry; Ꞓb, Bliss sandstone; Oep, El Paso limestone; Om, Montoya limestone; Sf, Fusselman limestone; Ch, limestone, mostly Permian, underlain by Devonian and Pennsylvanian to the north; Kcm, Comanche series; gr, granite; Tap, andesite porphyry; Qb, bolson deposits

Granite similar to the pre-Cambrian basement of other regions also underlies the Bliss sandstone, but as some of it cuts the Algonkian(?) and Paleozoic strata all has been classed as post-Paleozoic.

The Lanoria quartzite, with its sills of diabase, strongly suggests the Apache group of Arizona and is somewhat like part of the Millican formation near Van Horn. The El Paso limestone here is in its type locality, and the few fossils found in it, to a horizon within 100 feet of the bottom, are of Lower Ordovician age. Locally it lies directly on the pre-Cambrian rocks, but at most places it is underlain by the Bliss sandstone. There are fine exposures of this limestone on and near the roads at the south end of the Franklin Mountains. The Montoya limestone, which contains fossils of the Richmond fauna, is separated from the El Paso limestone by a hiatus representing much of late Ordovician time. The Fusselman limestone, containing a characteristic *Pentamerus* of Niagaran age, represents but small part of Silurian time. It is 1,000 feet thick and constitutes some of the highest summits in the Franklin Mountains. A small wedge of Devonian strata occurs in the northern portion of the range and also limestone containing Pennsylvanian fossils. The main mass is a noticeable feature on the south end of the mountain. The mountains to the south, in Mexico, are the Sierra Guadalupe and the Cerro de Muleros.

Wells in El Paso are reported to have penetrated valley fill to the depth of 2,285 feet. Fossil bones found in the Quaternary deposits have been determined as *Elephas columbi*, *Equus complicatus*, and *Tapirus haysii?*, representing an elephant, an ancient horse, and a tapir, all of which have been extinct for many centuries.

Tin ore was discovered in the Franklin Mountains in 1899, and various unsuccessful attempts have been made to work it profitably. The mineral is cassiterite, or tin oxide, and it occurs with quartz in the granite 12 miles north of El Paso.

The Franklin Mountains figure in many legends of the Indians and early settlers. One of the peaks suggests the outline of an Indian's head, traditionally said to be that of Cheetwah, a chief who was responsible for the massacre and exile of the Spaniards in New Mexico in 1680. There also is the reputed location of La Mina del Padre, a famous lost mine, the entrance to which, so the story runs, can be seen from the portal of the cathedral in Juárez by looking northeast exactly at sunrise "on the right day of the year."

In the Hueco Mountains, above the long talus slopes, there are caves which have yielded remains of the primitive people who once inhabited the region—fragments of head dresses, sandals, a cord skirt, and shell pendants, possibly indicating a ceremonial place. At Hueco Tanks are pictographs of various life forms and geometric designs in red pigment, and at the foot of the range near the New Mexico State line are the ruins of a pueblo of considerable size.

The Southern Pacific lines enter New Mexico on crossing the Rio Grande just west of El Paso, the State line being at midstream.

New Mexico.

This is actually in the western half of the State, the east boundary being meridian 103°, which is crossed by the railroad east of Alpine. The width of New Mexico is nearly 352 miles, and its greatest length from north to south is a little more than 390 miles. It covers an area of 122,634 square miles, or slightly more than that of Colorado. It includes the south

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of Carboniferous limestone in the range is, however, of Permian age.

Formations of Cretaceous age crop out near the south end of the range and on its western slope east of Montoya siding. The most extensive exposures are in the quarries that supply the cement works, where about 90 feet of hard massive gray limestone of the Comanche series is exposed. Higher Cretaceous beds appear on the opposite side of the Rio Grande. These strata are invaded by masses of porphyry which have been intruded in a molten condition. At several localities in the western part of the city there were formerly small outcrops of dark fissile shale that carried remains of *Inoceramus labiatus*, a characteristic Colorado fossil (Upper Cretaceous.) This shale also crops out on the south side of the river.

The heavy deposits of gravel and sand of the higher terraces are well exposed in the upper part of the city.

end of the Rocky Mountains; the general axis of uplift of which extends to El Paso, together with wide plateau areas in large part higher than 5,000 feet above sea level. The portion east of the Rio Grande was included in the Republic of Texas, and for relinquishing it and some other territory in 1850 Texas received $10,000,000. The rest of the State was acquired by the Mexican War and the Gadsden Purchase. (See p. 150.)

New Mexico was the most highly valued of the Spanish possessions in this country. It was first visited[93] by Friar Marcos de Niza, accompanied by the negro slave Estevan, in 1539, in their trip to the vicinity of the Indian pueblo of Zuñi, in search for the fabulous "Seven Cities of Cibola." In the following year Niza led Coronado to the Zuñi villages, where they arrived July 10. Later the Coronado expedition crossed the northern part of the State on a journey to Quivira. The first attempt at colonization was made at the mouth of the Rio Chama in 1598, and later at Santa Fe, by Juan de Oñate. (See p. 124.) It was terminated by the great pueblo rebellion of 1680, however, which forced the settlers (to the number of 1,000) to flee to El Paso, on the south bank of the Rio Grande, where a Franciscan mission had been started in 1659. Here their leader, Antonio Otermín, was successful in having a presidio, or fort, established. The reconquest of the region to the north was begun in 1692 by Diego de Vargas, and the next year recolonizing was again in progress. The region around Santa Fe became an important trading center. Each summer a fair was held at Taos at which furs and other products were obtained from the Indians by the traders in exchange for goods brought from the great annual winter fair in Chihuahua, where Indian products were in great demand. The main line of travel was along the Rio Grande, but after the winning of independence by Texas and the Mexican War great caravans came from the east over the Santa Fe trail.

When first organized as a Territory of the United States in 1850, New Mexico included the area which later became Arizona. It was given statehood in 1912. Its population in 1930 was 423,317 and the density of population 3½ persons to the square mile, having much more than doubled since 1890. More than half of the population are "Mexicans," a people consisting largely of descendants of Mexican settlers of long ago, together with many recent immigrants from Mexico, mostly of the peon class and largely of Indian origin.[94]

[93] It seems probable that Cabeza de Vaca may have reached the general locality of El Paso late in 1535, but he ascended the Rio Grande and crossed southwestern New Mexico on the way to Culiacán, in Mexico (Bolton, Sauer, and R. T. Hill).

[94] Gamio, Manuel, Sources and distribution of Mexican immigration into the United States, Mexico, 1930. Hoover, G. E., Our Mexican immigrants: Foreign Affairs, vol. 8, pp. 99–107, 1929.

Spanish is the language of a large proportion of the population of New Mexico, in many sections greatly preponderating over English.

A large number of Indians live in the several reservations, aggregating 7,340 square miles, in the northern and central part of the State. According to the report of the United States Commissioner of Indian Affairs the number was 28,736 in 1932, more than half of them Navajos. There are numerous ruins of settlements of aborigines, some of them of great antiquity, for there were large villages of these people at many places long before the coming of the Spaniards. Irrigation was extensively practiced by some of these ancient people.

According to the Census Bureau and the General Land Office the area of New Mexico is 78,401,920 acres, of which 14,383,995 acres (1931) is unreserved public land, 14,000,000 acres State land, 30,822,034 acres in farms and ranches, and 9,912,026 acres in national forests. Large numbers of cattle, sheep, and goats are pastured in the national forests at a small fee, under certain restrictions as to number of animals and their distribution to avoid overgrazing. About 12,000,000 acres, some of it in ranches, is included in land grants and Indian reservations.

About 2,000,000 acres is cultivated; of these 600,000 acres is under irrigation. The largest reclamation project is that of the Elephant Butte Dam, where the Rio Grande is impounded. The Pecos River is dammed near Carlsbad, and there are many small irrigation projects. United States census reports show that in 1929 the farms and ranches numbered 31,404, with a total value of $220,856,219, including buildings, fencing, and machinery, and the value of crops was $34,648,000. Much of the ranch land and other areas is used as pasture for livestock. Cattle in 1930 numbered 1,060,327, and goats and sheep numbered 2,587,600 and yielded wool and mohair valued at $3,392,114. A large part of the public land in New Mexico is not suitable for agriculture on account of its configuration and the aridity of theclimate.

The principal mineral resource of New Mexico is coal, which occurs in large fields west of Raton, near Cerrillos, and about Gallup, also in several minor areas, all in the northern part of the State. The total area underlain by coal is very great. Its production in 1930 was 1,969,433 tons (U. S. Bureau of Mines). There are mines of gold, copper, silver, lead, zinc, and other minerals, and a small production of clays, gypsum, and building stones. Potash is now being mined near Carlsbad, and petroleum and natural gas are obtained in the southeast corner of the State and in the San Juan Basin. According to the Bureau of Mines the values of metals produced in 1929 were, copper, $18,000,000; zinc, $4,520,000; lead, $1,397,000; silver, $582,000; and gold, $707,000—in all, $25,206,000. The yield of petroleum in 1929 was 1,830,000 barrels; in 1931 it was 15,360,383 barrels, mostly from Lea County, and a large amount of natural gas.

The climate of southwestern New Mexico is in general similar to that of areas of like elevation above sea level (4,000 feet or more) in a wide region extending from western Texas to southern California. The winters are mild, and although the summers are hot the air is so dry that the heat is much more endurable than in the sultry periods that occur in the summers of the Eastern and Central States. December is usually the coldest month, with an average temperature of about 40°. On nearly 300 days in a year there is sunshine for the greater part of the day, and storms of long duration are rare. The region lies outside of the normal storm track that extends over the central United States, and in consequence the weather is much more uniform than in the regions farther north and east. The principal rainy season is in July, August, and September. The annual rainfall in the wide valleys is mostly less than 10 inches, but on the higher ridges there are many rains and snows at times when there is little or no precipitation in the adjoining desert valleys.

NORTH LINE FROM EL PASO, TEX., TO MESCAL, ARIZ.

From El Paso westward to Tucson the Southern Pacific Railroad has two lines—one going by way of Deming and Benson and the other (formerly the El Paso & Southwestern Railroad) by way of Columbus and Douglas. Leaving El Paso, the north line of the railroad follows the north bank of the Rio Grande for some distance, with Mexico in plain view on the opposite bank. (Turn to sheet 18.) In about 1 mile a large smelter (pl. 18, *A*) is passed, and in 2 miles a cement plant, near which are large quarries in limestone (of Comanche or Lower Cretaceous age) in a downfaulted block at the south end of the Franklin Mountains. It is the presence of this rock and a mass of intrusive porphyry associated with it that causes the constriction of the river valley at El Paso (Spanish, the pass). At the entrance of this pass the railroad crosses the river into New Mexico and skirts the north side of the Cerro de Muleros, a high ridge which lies mostly in Mexico. At one place the railroad is within a few yards of the Mexican boundary, and one of the monuments is plainly visible on a hill near by.[95]

The Cerro de Muleros consists of a mass of limestone, shale, and sandstone of Cretaceous age penetrated and tilted by a large intrusive stock of porphyry.[96] The lower or quarry limestone in this succession (of Fredericksburg, Lower Cretaceous age) is well exposed

[95] The monument marking the beginning of the boundary between New Mexico and Mexico is on the south bank of the Rio Grande a short distance south of the west end of the south-line railroad bridge across the river. It indicates the location of the point near by where the "deepest channel of the Rio Grande touches the parallel of 31° 47′ north latitude," as prescribed in the terms of the Gadsden Purchase. (See p. 152.)

[96] In his description of the Cerro de Muleros, Böse gives the following section of the Comanche stratigraphy:

	Feet
1. Limestone, hard, white and light gray, with *Exogyra whitneyi*	30–65
2. Marl, yellow, with *Exogyra whitneyi* and *Hemiaster calvini*	30–65
3. Sandstone, red-brown, thick bedded, with *Exogyra whitneyi*	65–320

in the first railroad cut on the west side of the river. It is overlain by nodular and slabby limestones and shales containing large numbers of Washita fossils and grading up into a thick mass of dark shale in which there are deep cuts extending to and beyond Brickland siding. This shale is extensively worked for brick, hollow tile, etc., on the west bank of the river a short distance below the two railroad bridges.[97] The relations are shown in Figure 27 (p. 134).

Anapra.

Elevation 3,869 feet.
Population 27.*
New Orleans 1,195 miles.

Just beyond Anapra siding, where the north and south lines are close together and joined by switches to be used in case of necessity, the railroad grade ascends the terrace of valley fill, the edge of which margins the Rio Grande Valley in a long line of steep slopes. The top is attained near Strauss siding. Along the upgrade are many fine exposures of the gravel and sand of which the terrace is composed. This material was deposited by the Rio Grande at an earlier stage of its history, when it flowed west of the Cerro de Muleros and another high range to the south and emptied into the Guzman Basin in Chihuahua, Mexico. This was before its present course was developed through the "pass" at El Paso. Looking east from this grade, the traveler gets fine views of the long west slope of the Franklin Mountains, with its succession of westward-sloping

Strauss.

Elevation 4,104 feet.
Population 32.*
New Orleans 1,204 miles.

	Feet
4. Marl, brown, shaly; sandstone and limestone with *Alectryonia quadriplicata*	30–65
5. Marl, sandy, with shales and beds of limestone with *Pervinquieria trinodosa*	100–165
6. Shale, marl, and limestone, *Pervinquieria nodosa*	100–165
7. Limestone, sandy, thick bedded, calcareous gray sandstone, yellow and brown marl, and black shale with *Oxytropidoceras* cf. *O. belknapi*	30
8. Marl, brown, with beds of limestone and limy sandstone; *Oxytropidoceras bravoense*	30–65
9. Limestone, hard, thin bedded, gray, with *Turritella vibrayeana*	65–85

Böse suggests that No. 3 represents the Del Rio of Texas, No. 4 the Weno, No. 5 the Fort Worth and Denton, No. 6 the Kiamichi, and Nos. 7, 8, and 9 the upper Fredericksburg.

[97] In the upper part of the shale are sandy layers containing "*Nodosaria*" and other fossils indicative of the Del Rio horizon of the upper part of the Washita group (Comanche, Lower Cretaceous age). The shale is overlain by brown sandstone (possibly equivalent to Eagle Ford or the basal formation of the Upper Cretaceous), which is well exposed in a cut about 1 mile beyond the bridge, and this in turn is overlain by massive white limestone, also of Upper Cretaceous age, which is conspicuous near the tracks at intervals in the next half mile west. It contains numerous large shells of a species of *Exogyra*, a massive oyster with oddly curved beak, the species present here being peculiar to the later part of the Cretaceous period. In this area the railroad traverses a shallow syncline or basin, in which the sandstone underlying this limestone rises in the ridge to the west. Along the north line of the railroad, however, the relations are obscured in large part by the margin of the high-level deposits of the Rio Grande Valley, here consisting mostly of boulders of porphyry from the near-by Cerro de Muleros.

beds of limestone. Farther north is Organ Mountain, which, like the Cerro de Muleros, consists mainly of a great mass of porphyry intruded into the sedimentary strata. The central part of this igneous mass presents a massive columnar structure with spires having the appearance of huge organ pipes. The limestone into which this porphyry has been intruded has been greatly mineralized in places, notably at the Stevenson mine, east of Las Cruces, which has been a producer of silver and other ores for many years. Various rare minerals occur at this place. Up the valley is seen the winding ribbon of the Rio Grande, bordered in large part by irrigated fields. About 40 miles north, near Las Cruces, is the Mesilla Valley (may-see'ya), where a large amount of land is under intensive irrigation, utilizing water conserved by the Elephant Butte Reservoir,[98] 115 miles above El Paso.

From Strauss siding the railroad goes northwest over the wide alluvial plain that extends entirely across the southwestern part of New Mexico. This plain is characterized by vast numbers of a species of yucca (pl. 20, *A*) with shaggy trunk and a cluster of white flowers, which finds the sandy soil favorable for its growth. This plant, locally known as soapweed or palmilla, yields a valuable fiber, and its roots, known as amole, are used as a substitute for soap. The datelike fruit is greatly relished by cattle. The northerly trend of the railroad in this area is taken to avoid the large rugged area of volcanic rocks of the West Potrillo Mountains and its extension to the north.

The thick body of sand and gravel underlying the plain has been drilled for water at several points along the railroad. A boring at Lanark passes through 950 feet of beds, all supposed to be valley fill but possibly including some underlying Tertiary or Cretaceous strata. It found water which rises approximately to the level of the water in the Rio Grande Valley, 15 miles east. A boring at Kenzin, several miles beyond Lanark, passed through 550 feet of clay and sand with water in its lower part and continued through rock 527 feet farther.

Lanark.
Elevation 4,168 feet.
Population 40.*
New Orleans 1,214 miles.

Beyond Rutter siding great lava fields are in sight to the southwest, and near Afton and Kenzin sidings the tracks skirt the edge of a fresh recent-looking lava flow (pl. 19, *A*), which came from two conical craters plainly visible to the south and southwest.

[98] According to the United States Bureau of Reclamation the Elephant Butte Dam is 1,162 feet long, 306 feet high, and 154 feet wide at the base and contains 618,850 cubic yards of masonry. The reservoir extends 41 miles up the valley with an average width of 1¾ miles and a capacity of 2,638,000 acre-feet. It holds the floods of the Rio Grande and conserves the water for use when needed for irrigation all along the valley in southern New Mexico, western Texas, and Mexico.

Eight miles southwest of Rutter siding are two large "holes" in the wide terrace plain which have been a source of much wonderment for many years. They were originally called Los Corrales de Piedra (rock corrals). The more northerly, Kilbourne Hole, shown in Plate 18, *B*, is 300 feet deep and is encircled by a rim of loose material 50 to 150 feet high, so that at many places it has a total depth of 450 feet, with a maximum of 463 feet. The diameter is nearly

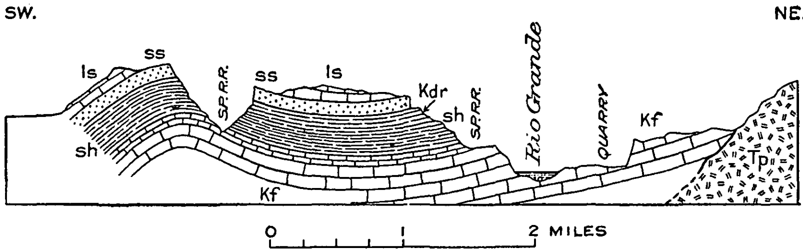


FIGURE 27.—Section southwest from cement quarry 2 miles west of El Paso, Tex. ls, Limestone, and ss, sandstone, of Upper Cretaceous age; Kdr, Del Rio horizon; sh, dark shale; Kf, Fredericksburg group; Tp, intrusive porphyry

2 miles. Hunts Hole, 2 miles south, is closely similar but smaller and has a rim of less height. A third one, Phillips Hole, to the southeast, is only about 50 feet deep and has no rim. The material in the wall of Kilbourne Hole (see fig. 28) is stratified sand similar to that which underlies the wide surrounding plain, capped by a 15-foot layer of lava, which thins out toward the southeast. The encircling rim is composed mostly of soft sandstone, strongly

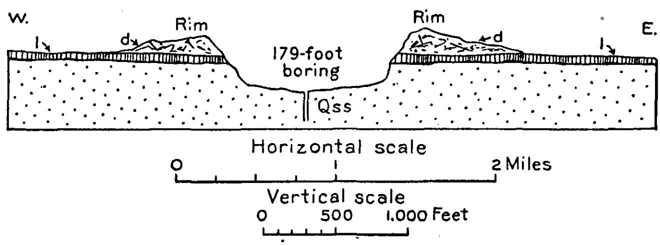


FIGURE 28.—Cross section of Kilbourne Hole, 8 miles west of Lanark, N. Mex. By W. T. Lee. l, Lava; d, ejected material; Qss, sand

cross-bedded and including some cinders, fragments of pumice, and many angular blocks of lava. A very remarkable fact is that much of the cross-bedding slopes toward the hole. It is believed that these two holes were caused by a volcanic explosion probably with outburst of water. Steam doubtless accumulated in sand under the lava sheet until the pressure was sufficient to cause the explosion.

In the sand penetrated by a 179-foot boring in the Kilbourne Hole part of the jaw of a Pleistocene horse was found at a depth of 70 feet, possibly in material that had caved from the sides of the hole. At the bottom of the boring a large amount of warm sulphur water was found.

Through Kenzin, Pronto, Aden, Chappel, and Dona sidings lava fields are in sight in every direction, especially on the south side of the railroad; most of them are recent outflows of scoriaceous basalt, but some are rhyolite of Tertiary age.[99]

Aden Crater, 4 miles south of Pronto siding and 7½ miles southeast of Aden siding, is a cone of lava undoubtedly marking the vent from which came one of the large recent lava flows skirted by the railroad in this vicinity. In its top is a deep blowhole or steam vent in the lava, in which many animal skeletons have been found, including coyotes, bobcats, and other animals of the present fauna, and a remarkable ground sloth which Lull [1] has identified as *Nothrotherium shastense*. The remains were partly buried in bat guano in a sloping chamber about 100 feet below the surface. The bones of the sloth were held by the original ligaments and tendons, and some of the periosteum, patches of skin, muscle fibers, and claws remain. Most of the hide had been devoured by fellow victims, whose teeth marks are visible on the remaining fragments. The sloth and other animals had evidently fallen into this hole, which is a natural trap in the crater rim. The time was many thousands of years ago, for the sloth is of a species found also in the Rancho la Brea asphalt in Los Angeles, where it occurs with bones of middle Pleistocene age. (See pl. 19, *B*.)

Just south of Aden is a prominent knob of rhyolite of the older volcanic series with a basalt flow at its foot, and 3 miles west are other

[99] Along or near the railroad in many parts of southwestern New Mexico there are thick accumulations of volcanic rocks which, like those in the Davis Mountains and other parts of western Texas, are the product of eruptions that continued for a large part of Tertiary time. They consist of alternating lava flows of various kinds, mainly of the varieties known as rhyolite, andesite, and latite, which differ in character and order from place to place and are locally separated by thick beds of light-colored tuff and volcanic ash. These lavas and beds of fragmental materials occur in sheets of varying thickness; some of them are several hundred feet thick and of wide extent. They are much older than the recent basalt flows that occur in some of the valleys. Undoubtedly these older lavas were originally much more extensive and continuous than at present, for they have been uplifted, tilted, and in large part removed or cut back by erosion. They were erupted from cracks or craters, some of which are still recognizable by their character or configuration. The tuff is fine grained, is mostly of light color, and consists mainly of ash and small grains of pumice. It was blown out of vents by steam and deposited by wind or water in great sheets over the lava flows or other surfaces; in most places it was covered by later lava flows, the eruptions generally consisting of alternations of lava outflows and ejections of fragmental materials. There were also mud flows, consisting of material similar to the tuff and ash, mixed with water, which poured out of craters or vents and spread over the surface in plastic condition, in places to a thickness of 50 feet or more. (See p. 164.)

[1] Lull, R. S., A remarkable ground sloth: Yale Univ. Peabody Mus. Mem., vol. 3, pt. 2, 1929.

knobs of rhyolite tuff capped by basalt of the older succession. The volcanic area here extends so far north as to cause considerable northerly deflection of the railroad to reach a long tangent that passes through Chappel and extends beyond Carne. At Chappel the lava fields are left behind, but detached igneous masses are in sight not far to the south and north. Two miles south of Dona siding is the very prominent Providence Cone, rising nearly 300 feet above the surrounding desert plain. Apparently it was the orifice of an old volcano, but any flow of which it may have been the source has either been removed or lies beneath the valley fill. Far to the west from this place extends the level-floored Mimbres Valley (mim'brace), which merges

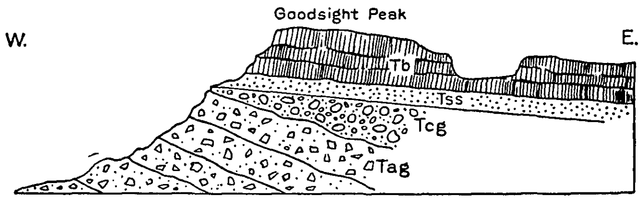


FIGURE 29.—Section through Goodsight Peak, 15 miles northwest of Cambray, N. Mex. Tb, lava (basalt); Tss, gray sandstone; Tcg, conglomerate; Tag, agglomerate

into the Lake Guzman Desert, Mexico. This extensive basin has no surface outlet to the Rio Grande.

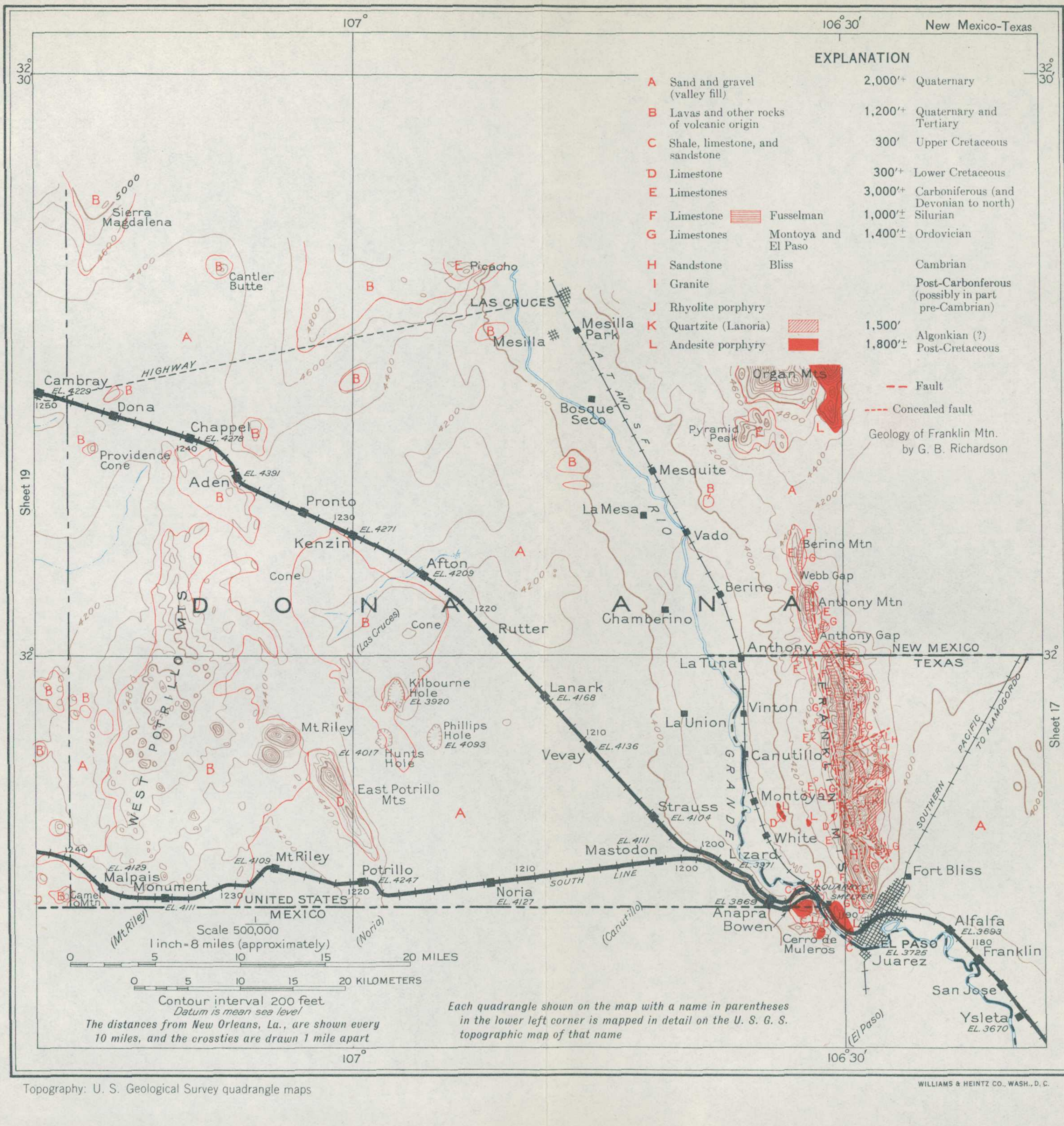
Cambray.
Elevation 4,229 feet.
Population 40.*
New Orleans 1,250 miles.

Near Cambray, the highway crosses the railroad, and after following the track for some distance, goes due west to Deming. It comes from El Paso by way of Las Cruces, passing through a country better suited for tourists than the sandy and desolate region traversed by the railroad.

The old Butterfield stage route to California came through Mesilla, just south of Las Cruces, but crossed the desert in a course north of the present highway; it passed through a gap just south of Goodsight Peak and entered Cooks Peak Range in its southern extension, where old Fort Cummings was located adjacent to an excellent spring. (Turn to sheet 19.)

North of Cambray are the prominent Goodsight Mountains, which consist of a thick sheet of basalt capping a mass of agglomerate and tuff; the basalt dips gently to the east, as shown in Figure 29, but rises again in the mountains farther east.[2]

[2] The agglomerate in the east slope is a very massive rock and consists mostly of large and angular fragments of andesite in a more or less crystalline matrix. This rock appears again in many other parts of the region and is the product of a widespread eruption of late Cretaceous or early Tertiary age. It is overlain unconformably by gray conglomerate and 40 feet of soft gray sandstone, both consisting largely of volcanic materials and probably of Pleistocene age. The basalt is in three sheets, representing three effusions of lava. Much of it is vesicular or full of small holes due to steam in the lava when it was poured out. Evidently the agglomerate was tilted and planed off by erosion prior to the deposition of the overlying beds.



Topography: U. S. Geological Survey quadrangle maps

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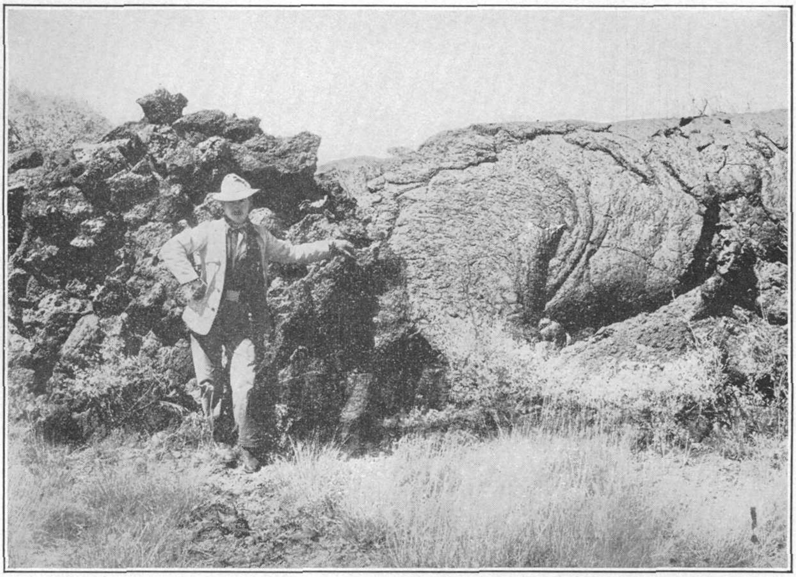
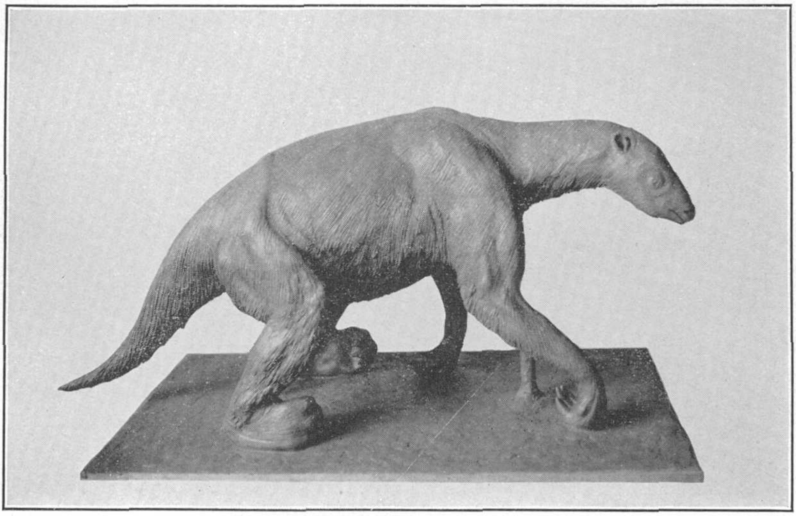
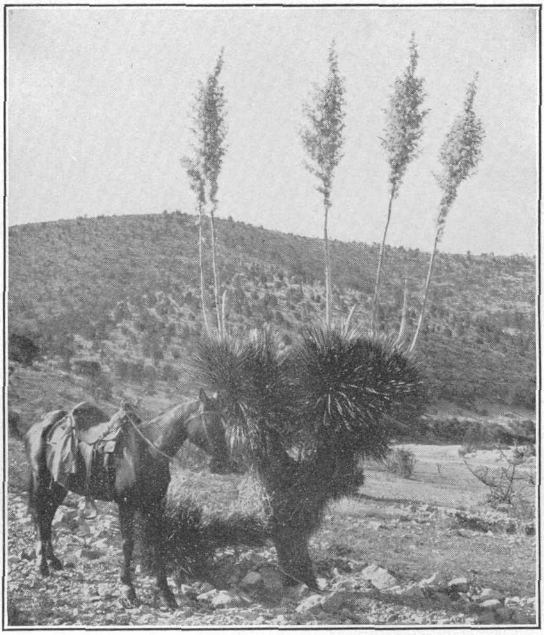


A. TYPICAL EDGE OF A RECENT LAVA FLOW IN SOUTHWESTERN NEW MEXICO
The ropy rounded surfaces and the broken variety at the left are characteristic. (Hill.)



B. RESTORATION OF GIANT SLOTH
From remains found in Afton Crater, N. Mex.



A. "LILIES OF THE DESERT"

Yucca in blossom in the region west of Deming, N. Mex.

B. OBTAINING A QUENCH OF WATER FROM THE BIZNAGA CACTUS

Sometimes a life saver in the deserts of the Southwest.

The southern part of New Mexico is underlain by an extensive series of formations representing various parts of geologic time from pre-Cambrian to Recent. Most of them are also present in western Texas, as described in preceding pages. Those that are exposed near Deming and westward near the Southern Pacific Railroad are listed in the following table:

Geologic formations of southwestern New Mexico

Age	Group and formation	Character and general relations	Thickness (feet)
Recent.	Alluvium.	Sand, gravel, and silt of river bottom, desert floors, and fans.	0–1,000
	Unconformity		
Pleistocene and Tertiary.	Volcanic rocks and associated deposits.	Lavas, ash, tuff, agglomerate, conglomerate, and sandstone.	700–1,400
	Unconformity		
Upper Cretaceous.	Colorado shale.	Dark shale.	(?)
	Unconformity		
Lower Cretaceous (Comanche).	Sarten sandstone.	Gray sandstone.	450
	Limestone of Comanche age.	Limestone.	
	Unconformity		
Triassic?	Lobo formation.	Shale, conglomerate, and sandstone, partly red.	0–350
	Unconformity		
Permian.	Gym limestone.	Limestone, massive and slabby.	30–1,000
	Unconformity		
Pennsylvanian.	Magdalena formation.	Limestone, with some shale.	0–40
	Unconformity		
Mississippian.	Lake Valley limestone.	Limestone.	0–700
Devonian.	Percha shale.	Black shale.	0–175
Silurian.	Fusselman limestone.	Limestone, massive.	100–300
	Unconformity		
Ordovician.	Montoya limestone.	Limestone with cherty member above, sandy below.	0–300
	Unconformity		
	El Paso limestone.	Limestone, slabby; weathers light gray.	500–800
Cambrian.	Bliss sandstone.	Sandstone, massive to slabby, glauconitic.	30–200
	Unconformity		
Pre-Cambrian.		Granite and schist.	

Deming.

Elevation 4,337 feet.
Population 3,377.
New Orleans 1,276 miles.

Deming is a long-established commercial center, railroad junction, and headquarters for mining and irrigation interests. Here the Atchison, Topeka & Santa Fe Railway from Albuquerque passes on the way to Silver City, and there is a branch railroad connecting with the south line of the Southern Pacific at Hermanas. There is now but little mining in the immediate vicinity, but ores of various kinds have been produced in the adjoining mountains, notably fluorite (calcium fluoride) from mines 10 miles northeast, and manganese ore from a mine in the north end of the Little Florida Mountains, 12 miles southeast. There are extensive mines at Silver City and near Santa Rita, about 50 miles northwest of Deming.

However, the underground water in the sand and gravel about Deming and southward is the most important economic resource in the region, and it is utilized extensively in irrigation.[3] It lies

[3] Described by N. H. Darton in U. S. Geol. Survey Bull. 618 and Water-Supply Paper 345–C.

from 25 to 150 feet below the surface. A large area is underlain by the water-bearing beds, but the largest volume at moderate depth is found about Deming and in the lower part of the wide bolson extending southward from that place along the west side of the Florida Mountains (flo-ree'dah). It is believed that the water is an extension of the underflow from the Mimbres River with additions from confluent streams, and there is some increment from the local rainfall, which amounts to about 10 inches a year. Although most of the rain water evaporates, a certain proportion passes underground where the soil is porous. There is, however, a return of part of this water to the surface by capillary action, which is strong in arid regions. The volume of water stored in the valley fill is great, but it is well known that such a supply can be depleted if it is drawn upon more heavily than it can be replenished. To ascertain these conditions a careful investigation was made by the United States Geological Survey,[4] cooperating with the State of New Mexico, to ascertain the amount of water available. It was estimated that the average annual increment of the ground water during 20 years was from 10,000 to 11,000 acre-feet, with a high rate in wet seasons, and therefore that this should be the limit of its utilization. The rate of movement down the valley is mostly from 2 to 3 feet a day. Heavy pumping reduces the level of the underground water table.

Irrigation by well water began in 1908, and in 1914 nearly 200 pumping plants had been installed or were under erection. As most of the operators were inexperienced in agriculture many of the projects were not profitable, and in 1919 only 25 pumps were in operation. In 1930 there had been considerable revival of the industry, and 116 pumps were supplying water for irrigation and other uses, and about 6,000 acres were under cultivation, mostly with very satisfactory returns. The water is generally less than 50 feet below the surface and is pumped with small gasoline engines, with a yield of 200 to 1,000 gallons a minute. Various crops are raised, including a large acreage of beans and considerable alfalfa. The amount of water necessary varies with the soil and crop, but 2 to 2½ acre-feet to the acre is used. A well producing 500 gallons a minute can irrigate 25 acres in about three days, but this must be repeated several times during the growing season.

The wide desert about Deming, known as the Florida Plains, is a part of the valley of the Mimbres River (Spanish, mimbres, water willow), past and present. It is heavily covered by valley fill, the bottom of which appears not to have been reached by borings 710, 980, and 1,665 feet deep in Deming and vicinity. Out of the level surface of this plain or valley rise several high mountains and ridges, such as the Florida Mountains; the Tres Hermanas Mountains,

[4] Results given in U. S. Geol. Survey Water-Supply Paper 637-B, by W. N. White.

far to the south; the Victorio Mountains, to the west; the Goodsight Mountains, to the east; and Cooks Range with its prominent culminating Cooks Peak, to the north. There are also many isolated ridges and buttes that rise abruptly from the desert plain. One of these, Black Mountain, a prominent isolated mesa 10 miles to the northwest, is capped by an eastward-dipping sheet of basalt. Another conspicuous feature is Red Mountain, 10 miles southwest of Deming, which consists of a large mass of rhyolite.

The Florida Mountains, southeast of Deming, form the most striking feature of the landscape, with exceedingly high rough crags all over their higher summits. At one point there is a jagged hole through the crest known as Arco del Diablo (bridge of the devil), 85 feet high by 250 feet long, which is visible from Cambray to Luxor.

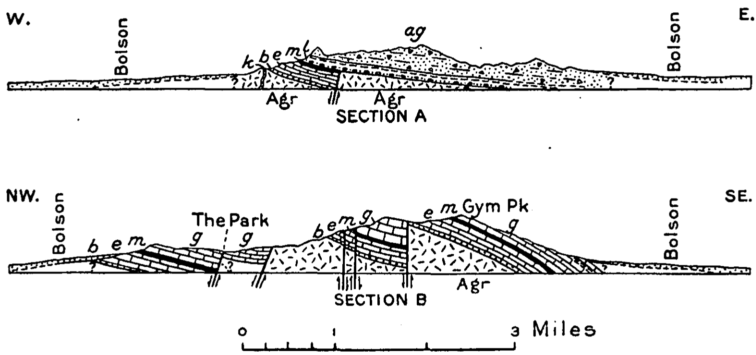


FIGURE 30.—Sections across Florida Mountains, Luna County, N. Mex. A, Through Capitol Dome, near the north end; B, through Gym Peak. *b*, Bliss sandstone; *e*, El Paso limestone; *m*, Montoya and Fusselman limestones; *l*, Lobo formation; *g*, Gym limestone; *k*, keratophyre dikes; Agr, granite; *ag*, volcanic agglomerate

The northern half of the range, like the outlying Little Florida Mountains, consists of agglomerate and other igneous rocks; the southern half is pre-Cambrian granite overlain by sandstones and limestones of Cambrian to Permian age. The rocks are tilted and traversed by several faults of moderate amount. The principal relations are shown in the sections in Figure 30.[5]

[5] In general the range is a tilted block of pre-Cambrian granite capped by sedimentary strata in an eastward-dipping monocline that is possibly the eastern limb of an anticline whose axis lies under the bolson on the west, or the uplift may be bounded on that side by a fault. At Capitol Dome, at the north end of the range, the Paleozoic rocks and agglomerate deposits all dip to the east-northeast, and the underlying granite is exposed at the foot of the western slope. This easterly dip, with repetition of the limestones by faulting, is exhibited again farther south in the center of the range, where there is a profound fault that trends northeast with an upthrow that lifts the granite 2,000 feet or more in the south end of the range. Gym Peak consists of Permian limestone dipping east; on the west side of the peak this

The ridge known as the Little Florida Mountains consists of a thick sheet of felsitic or vitreous rhyolite, included in a thick deposit of agglomerate apparently somewhat younger than the beds constituting the north end of the Florida Mountains. It is possible, however, that a fault may pass between the two ranges. The structure is shown in Figure 31, in which section A shows the relations that prevail along the greater part of the ridge and section B shows features

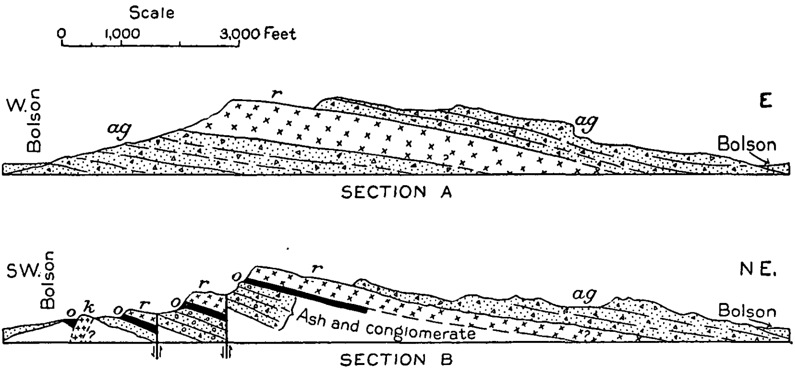


FIGURE 31.—Sections across the Little Florida Mountains, N. Mex. A, Across center of range; B, 1½ miles farther south. *ag*, Agglomerate; *r*, felsitic rhyolite; *o*, obsidian; *k*, keratophyre

of the faulted portion farther south. Manganese ore is mined in the north end of the range.

The conspicuous ridge a few miles north of Deming is Fluorite Ridge, an outlier of the south end of the Cooks Range. It consists of a thick central mass of porphyry so intruded as to cause an irregular dome-shaped uplift, elongated to the northwest and southeast. The strata on the south and east sides of the dome stand nearly vertical, but those on the north and west sides have more moderate dips. The plane of intrusion is low in the Paleozoic strata at the southeast end of the uplift, but it rises rapidly toward the north and west,

limestone extends westward over the uneven edges of the underlying Fusselman (Silurian), Montoya (Ordovician), and El Paso (Ordovician) limestone for some distance. There may be an overthrust at this place. Possibly also Percha beds of Devonian age are buried here, for black shale appears along a cross fault southwest of Gym Peak. The Gym limestone is about 1,000 feet thick, but its upper surface is eroded.

The Lobo formation, which occurs in the northern part of the Florida Mountains, with a thickness of about 300 feet, consists largely of reddish and gray shale and gray to pinkish impure limestone, with coarse basal beds. Near Capitol Dome, a conspicuous peak on the north end of the mountains, this formation extends across a fault (shown in fig. 30, A) which lifts the granite about 1,000 feet to the level of the top of the El Paso limestone. The uplifted block was eroded to a plain before the deposition of the Lobo beds, and therefore their age is believed to be post-Paleozoic, probably Triassic.

finally reaching the base of the Sarten sandstone (Cretaceous). There are several faults at the south end of the ridge.[6]

In the southeast end of Fluorite Ridge a large amount of the mineral fluorite has been mined. It consists of calcium fluoride and is of bright-green color, crystalline structure, and glassy aspect. It is used extensively in steel making. The mineral occurs in several steeply dipping veins, mostly in the porphyry; these varied from a few inches to 12 feet or more in thickness with a general range in the workings from 2 to 5 feet. Much of the fluorite was more than 90 per cent pure. For several years this material found a ready market at Pueblo, Colo., and other places, and the annual production averaged about 5,000 tons, but cheaper sources of supply were found and the workings are now abandoned.[7]

The Cooks Range, lying north of Fluorite Ridge and a very conspicuous feature from Deming, is an irregular dome due to a great

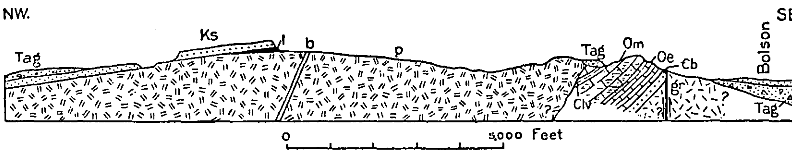


FIGURE 32.—Section across Fluorite Ridge, N. Mex. Tag, Agglomerate; Ks, Sarten sandstone; l, Lobo formation; Clv, Lake Valley limestone; Om, Montoya limestone overlain in part by limestone of undetermined age; Oe, El Paso limestone· Єb, Bliss sandstone, gr, granite and diorite; p, porphyry; b, diabase dike

central intrusion of porphyry which brings into view a floor of pre-Cambrian granite and the succession of Bliss sandstone, El Paso,

[6] Red granite and diorite (pre-Cambrian) are exposed in the lower southern slopes and also a breccia of mica schist fragments. The Bliss sandstone is overlain by a regular succession of strata to and including the lower portion of the Lake Valley limestone. Some of the beds are greatly squeezed, notably the El Paso limestone, which presents a thickness of only 400 feet. Some huge masses of white siliceous rock at the east end of the range have undoubtedly replaced limestone, probably of both Lake Valley and Montoya age. A profound fault that extends along the east side of the ridge appears to lift porphyry, although it is possible that this igneous rock was intruded after the faulting, and there is some suggestion that it is younger than the agglomerate which is exposed in the slopes on the east side of the ridge. The west end of Fluorite Ridge consists largely of Sarten sandstone penetrated by porphyry and overlain by Tertiary agglomerate. A small exposure of granite in the locality indicates either faulting or overlap, for in places the Sarten sandstone lies directly on granite. Goat Ridge, a short distance to the west, is an elongated dome with axis trending northwest that exposes Sarten sandstone. The underlying Lobo formation (Triassic?) is revealed in part of the area, and granite appears on the northwestern slope of the ridge. The Pony Hills, a small group of knobs just north of Fluorite Ridge, consist of irregular outcrops of granite and Sarten sandstone in juxtaposition, owing either to overlap or to faulting.

[7] Darton, N. H., and Burchard, E. F., Fluorspar near Deming, N. Mex.: U. S. Geol. Survey Bull. 570, pp. 533–545. 1911.

Montoya, and Fusselman limestones, Percha shale, Lake Valley, and Gym limestones, limestone of the Magdalena group, Lobo formation, Sarten sandstone, and Colorado shale. The southern slope consists of agglomerate, Sarten sandstone, and Colorado shale. Some relations to the central and southern parts of the range are shown in Figure 33.

Cooks Peak consists of a large laccolithic mass of granodiorite porphyry which was intruded in a molten condition into the Lake

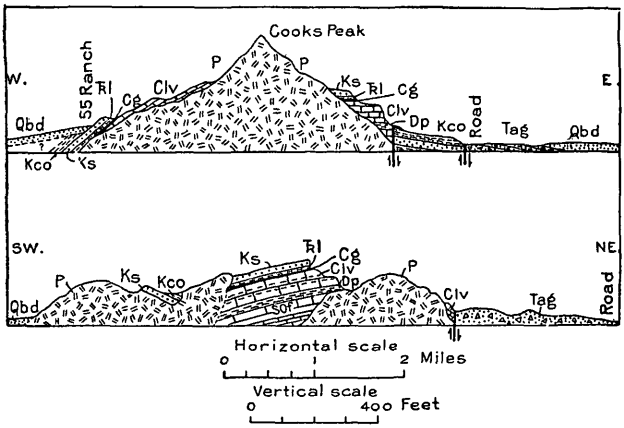


FIGURE 33.—Sections across Cooks Range, N. Mex. Upper section, through Cooks Peak; lower, about 3 miles south of Cooks Peak. Base of sections, 5,000 feet above sea level. P, Porphyry; Tag, agglomerate; Qbd, valley fill; Kco, Colorado shale; Ks, Sarten sandstone; Ŧl ,Lobo formation; Cg, Gym limestone and Magdalena formation; Clv, Lake Valley limestone; Dp, Percha shale; SOf, Fusselman and Montoya limestones on El Paso limestone

Valley limestone and adjoining strata. Several other large porphyry intrusions occur southwest and south of the high central area.

On the west slope of the range northwest of Cooks Peak and in the slopes south of that peak the Sarten sandstone is exposed, overlain by shale of Colorado age (Upper Cretaceous). It contains fossils of Comanche age (Lower Cretaceous). This sandstone constitutes the prominent dip slope 2 miles south of Cooks Peak, which becomes Sarten Ridge to the south, where the Sarten sandstone is underlain by the Lobo formation, the Gym and Lake Valley limestones,[8] and a small amount of Percha shale.

[8] The Lake Valley limestone (early Mississippian), which crops out in several places in the Cooks Range, is overlain by about 40 feet of dark-gray shale with limy layers of the Magdalena formation, and this in turn by Gym limestone, here only 20 to 30 feet thick, which is believed to be a representative of part of the Chupadera formation of New Mexico. In this region it is overlain by the Lobo formation, about 100 feet thick, consisting principally of reddish or brown sandstone or shale. The Lobo beds are also exposed on Goat Ridge and in the deep hollow near the south end of Sarten Ridge.

From Deming the railroad line goes slightly south of west on a tangent 37 miles long over a great desert plain, with a rise of only 250 feet in 33 miles to the Continental Divide.

At Tunis siding Black Mountain seems near on the north, showing in cross section its eastward-dipping cap of black basalt about 250 feet thick, lying on volcanic ash and sand of which 500 feet is exposed, cut by rhyolite. Still nearer, to the south, is the craggy butte known as Red Mountain, so named from the pinkish tint which it shows in some lights. It consists of nearly white felsitic rhyolite, apparently lying on agglomerate. Probably this igneous mass was extruded in a highly viscous condition, so that it piled up thickly without extending far beyond its present area. It is regarded as of Tertiary age.

The Snake Hills, a group of low mounds in the plain 3 miles south of Red Mountain, consist of the upper member of the El Paso limestone and the lower member of the Montoya limestone.

Gage.

Elevation 4,590 feet.
Population 20.*
New Orleans 1,296 miles.

North of Gage are some conspicuous rounded and pointed buttes known as the Grandmother Mountains, composed of felsitic rhyolite similar to the rock of Red Mountain and doubtless extruded at the same time. Other buttes farther north include Cow Cone, which also is part of a large mass of felsitic rhyolite. In the distance to the north are the mountains in which lies Silver City. South of Gage are the Victorio Mountains, which present many features of geologic interest. The main ridge consists of a sheet of hornblende andesite about 200 feet thick underlain in part by a thin sheet of rhyolite. It dips 20°–25° NNE. In the hills just south of this ridge there are, in succession, the El Paso, Montoya, Fusselman, and Gym limestones.[9] Devonian, Mississippian, and Pennsylvanian time apparently is not represented. Figure 34 shows the principal features in both parts of the uplift.

[9] The Gym limestone, about 300 feet thick, crops out in a zone about 2,000 feet wide marked by knobs on the south side of the range. It appears to lie on the Montoya limestone, but possibly there is a separating fault. It contains several distinctive fossils. The Gym is overlain unconformably by 700 feet of shale and sandstone, mostly reddish, which resembles the Lobo formation (Triassic?) but may be much younger. Dark purplish-brown fine-grained massive shale and sandstone predominate, but several beds of coarse conglomerate are included which contain boulders of andesite and near the top some greenish quartzite carrying pebbles of fossiliferous Paleozoic limestone. There are various unconformities in the succession, but all the strata have practically the same attitude. There are several faults and some obvious overlaps. The Fusselman limestone carries an interesting fauna of Niagaran corals and lies on cherty beds of Montoya limestone with Richmond fossils. The Montoya includes a prominent sandstone member. There are several intruded dikes, mostly of porphyry. A small amount of mineralization has occurred along the fault in the west side of Mine Hill, but the mining operations on this zone apparently did not yield a return sufficiently satisfactory to warrant extensive development.

About halfway between Wilna and Ladim sidings the railroad crosses the Continental Divide at an elevation of 4,587½ feet. A sign marks the place, which is on the broad bolson or valley fill of unknown thickness, far from the rock ledges in the hills to north and south. About a mile north of Ladim siding there is a low butte consisting of limestone with much chert which is probably of Ordovician age (Montoya) or possibly of Lower Cretaceous age. (Turn to sheet 20.) To the west is a gentle down grade into Lordsburg, but with the course changing to northwest to pass the north end of Pyramid Mountain. At Separ siding are wells over 600 feet deep from which about 40,000 gallons of water a day is pumped for use by the locomotives. It is contained in gravel and sand in the thick deposit of alluvial fill which underlies this valley. About 12 miles north of

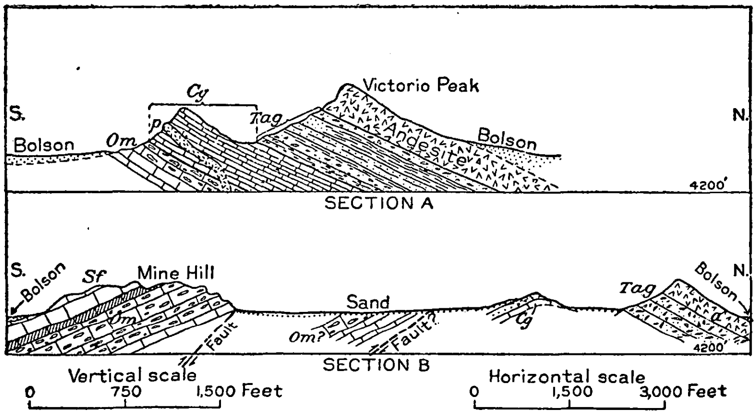
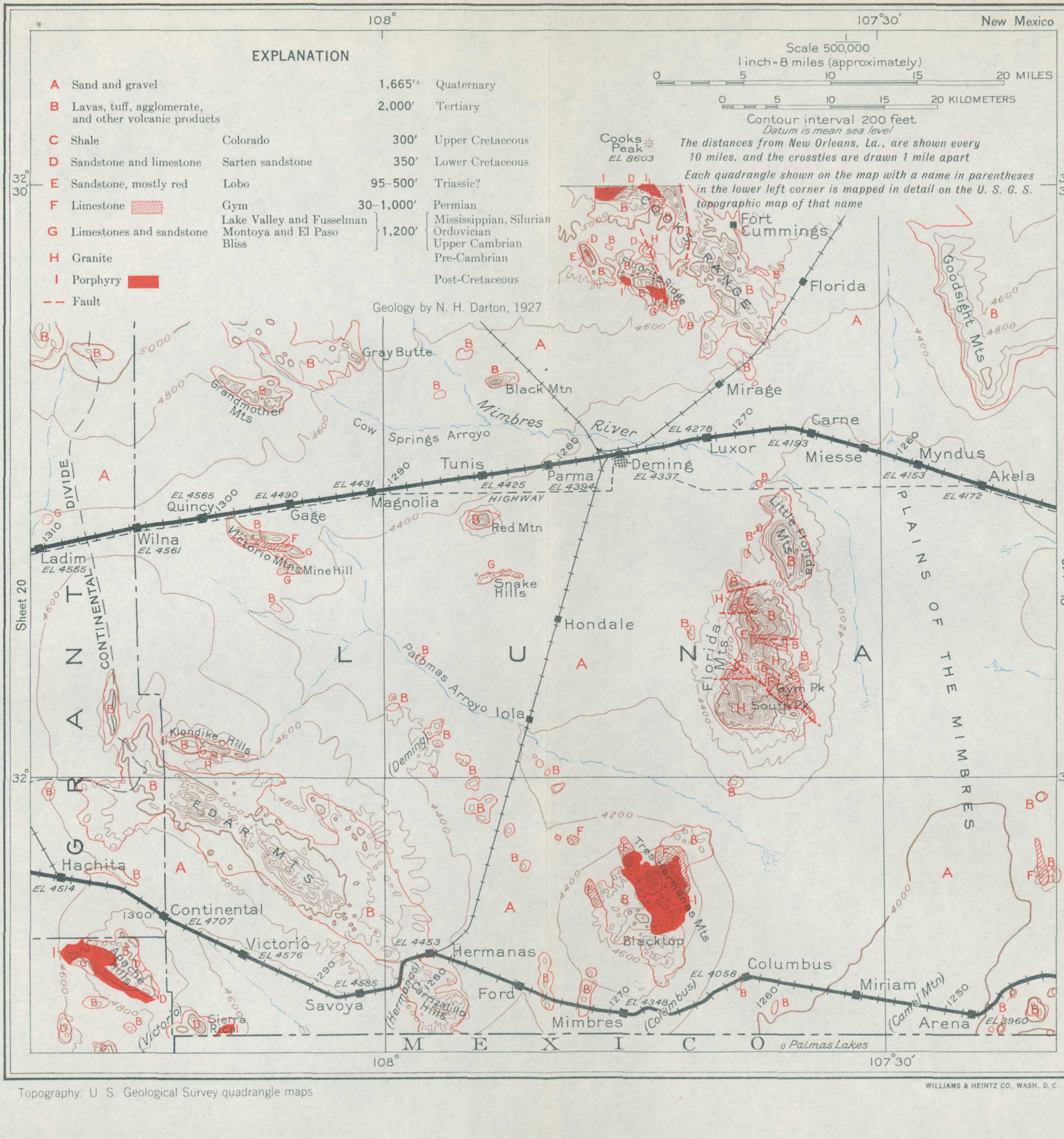


FIGURE 34.—Sections across Victorio Mountains, south of Gage, Luna County, N. Mex. *a*, Andesite; *Tag*, agglomerate, shale, and sandstone; *Cg*, Gym limestone (Permian); *Sf*, Fusselman limestone; *Om*, Montoya limestone; *p*, porphyry dike

Separ are the foothills of the Burro Mountains, consisting of granite overlain to the east by volcanic rocks forming high conical buttes. Considerable turquoise has been obtained from these mountains, mainly by the Indians. This beautiful gem mineral was mined by American aborigines at an early time, for beads and pendants of it are found in ruins at Chaco Canyon, N. Mex., the earliest of which (according to the annual growth rings in some of the timbers) probably date back to the time of Christ, and turquoise is mentioned in many of the old myths of the pueblo people of the Southwest. In 1539 Marcos de Niza met Sonoran Indians who worked in turquoise mines in New Mexico, probably those at Los Cerrillos, which for centuries were the most productive source of the mineral in this country. The very old mines in the Burro Mountains were relocated years ago and worked for some time.

Far to the south is Big Hatchet Mountain, and to the southwest the Pyramid Mountains are prominent. The yucca (see pl. 20, *A*),



Topography: U. S. Geological Survey quadrangle maps

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which has been abundant for many miles along the tracks, continues to be the most noticeable element in the sparse vegetation. It blooms in June and early July.

Lordsburg.
Elevation 4,248 feet.
Population 2,069.
New Orleans 1,336 miles.

Lordsburg is a busy town with local stock and mining interests, and a Government airport, which is extensively utilized throughout the year. A branch line leads to the mining community of Clifton, Ariz., and another branch goes southeast to Hachita, on the south line of the railroad. Lordsburg lies just north of the north end of the irregular group of ridges, buttes, and peaks of the Pyramid Mountains, in which there are several active mines. One of these, known as "the 85," is in sight as the train approaches Lordsburg. It lies in a cove at the foot of the mountains and ever since its start, in 1885, has been productive of gold, silver, and copper. The mineral veins cut volcanic rocks, and some of them crop out as dark "reefs," which are conspicuous in the hill slopes. There are other mines farther south, and Gold Hill, 14 miles northeast of Lordsburg, has long been a producer of gold from quartz veins in the old crystalline rocks. The Pyramid Mountains consist of an extensive succession of igneous flows and intrusions, apparently of Tertiary age. The greater part of the range is andesite of porphyritic texture, but there are masses of diorite porphyry in the western part of the mining district, near Lordsburg. Considerable brecciation has occurred in parts of the area, and there are many mineralized veins, some of which have yielded a large amount of ore containing silver, lead, copper, and gold. The Lordsburg district furnishes 60 per cent of the New Mexico production of gold, also considerable copper, mostly from the deeper workings. The total metal production from the district is estimated at $18,000,000. All the ore is shipped to smelters at El Paso, Tex., and Douglas, Ariz. The deepest shaft is 1,700 feet deep.

Passing around the end of the foothills [10] of the Pyramid Mountains west of Lordsburg and between a group of outlying hills of lava, the railroad deflects southwestward to reach Steins Pass. It crosses the bare wide level-floored basin of the Playa de los Pinos, which contains two large "alkali" flats north of the railroad. Sometimes these flats are covered by water, but usually they present a glistening surface of crystalline salts, often giving rise to striking mirages. This basin is a northern extension of the Animas Valley (see p. 168), so deeply filled with detritus that the rise to the divide at Steins is only about 200 feet.

[10] One of these hills a mile west of Lordsburg, south of the railroad, consists of quartzite faulted against igneous rocks and probably of Lower Cretaceous age. The hills just northwest of Pyra siding are due to a sheet of lava capping volcanic tuff (Tertiary). This rock is a latite carrying phenocrysts of plagioclase and hornblende in a fine-grained groundmass rich in orthoclase.

The highway to Douglas and the Southwest leaves the railroad a short distance east of Steins (locally pronounced steens) and reaches the south line of the railroad at Rodeo. There has been considerable mining at several places north and south of Steins. The Carbonate mine, about 3 miles south, is on the eastern slope of the Peloncillo Mountains. These mountains, made up of lavas, form a long, narrow ridge which extends far to the north and south along the western margin of New Mexico. The jagged crest line presents many conical peaks, each resembling a pelón (Spanish for a cone of raw sugar). Peloncillo (pay-lone-see'yo) is the diminutive form of pelón.

Steins.
Elevation 4,352 feet.
Population 40.*
New Orleans 1,355 miles.

The gap through which the railroad crosses this range is known as Steins Pass, but the divide is at Steins station, a short distance east of the rocky gateway. The pass has high walls on the north side and rocky slopes to the south, all consisting of lavas that were erupted in early Tertiary time, part of a succession of flows 1,200 feet or more in thickness which have been tilted gently to the north and northeast; on the east are two old volcanic cones from which doubtless some of the lava flows originated. In the large stone quarry in the north wall of the pass a contact of two flows of the lava (andesite on rhyolite tuff) is strongly marked by difference in color. Here both rocks have been quarried for ballast for the railroad and for other uses. In the quarry a dike cutting the lava is well exposed. Vertical jointing is a very conspicuous feature, especially on the west slope of the mountain.

From Steins Pass there is a magnificent view to the west across the wide San Simon Valley (see-moan') to the Chiricahua (an Indian name pronounced nearly like cheery cow) and Dos Cabezas Mountains, which are separated from each other by Apache Pass. In the high crest of the Chiricahua Mountains is a profile of a huge face directed skyward, known as Cochise Head, from the famous Apache chief Cochise (co-chee'say). The prominent straight nose is easily recognized; the chin is to the north.

Steins Pass has long been an avenue of access into eastern Arizona by way of the San Simon Valley and thence west by Apache Pass or by Railroad Pass at the north end of the Dos Cabezas Mountains.

This region with its wide adjacent valleys was the scene of many Apache depredations in the early days of travel and settlement. Much blood was shed during Cochise's outbreak, especially when the frontier troops were called east for the Civil War. The stages then ceased to run, and a large proportion of the white settlers left the country. Many persons were killed. The Apache Indians raided ranches, mines, and travelers, sallying forth from hiding places inaccessible to riders less skilled than themselves, where a few Indians could resist many times their number. They were difficult to fight, for they avoided open engagements and could travel fast and far on their ponies. It is stated that Cochise's enmity was aroused by an act of treachery of an inexperienced young Army officer who, when Cochise, under a flag of truce, came to deny that his tribe had abducted a white child, seized him and a group of his chiefs. Cochise escaped, but his chiefs were hanged. This was in 1860. It was Gen. O. O. Howard who 12 years later finally arranged a peace pact with Cochise, a treaty which the chief required his band to observe until his death in 1874.

In the Chiricahua Mountains is a great cavern where the remnants of Cochise's band had the custom of gathering after his death to honor him with weird ceremonies. These mountains were also the headquarters of Arizona Kid, one of the last of the bad Apaches.

The Chiricahua Apaches were repeatedly placed on reservations, but they were subject to a vacillating Federal policy, with the result that they went on the warpath at frequent intervals. Chato, Gerónimo, Nachi, Loco, and Victorio were notorious chiefs. On his last escape from the reservation in the White Mountains, Gerónimo and his band, slaughtering people as he went, traveled south along the New Mexico-Arizona line as far as Steins Pass. Here he turned west to a hiding place in the Chiricahua Mountains. After 10 years of this warfare the Apaches were subjugated in 1886 by Gen. Nelson A. Miles, and their leaders removed from the territory.[11]

Arizona.

At Cavot siding, 4 miles west of Steins station, the State of Arizona is entered. The State line is on the thirty-second meridian west of Washington (very nearly 3 miles west of longitude 109° west of Greenwich) and was so defined by law when the Federal Government was attempting to establish an initial meridian passing through the National Capital. Most of its western boundary is formed by the Colorado River, and its average width is about 315 miles. With an area of 113,956 square miles, it is the fifth State in size in the Union, being nearly as large as

[11] Victorio, after various raids and atrocities in Mexico, Texas, and Arizona, was killed in 1880, when with 98 of his band he was attacked by Mexican troops at Tres Castillos, Mexico. It is said that his scalp was exhibited in Mexico City. Nachi was Cochise's son.

Gerónimo (Spanish for Jerome), who was particularly notorious, was born about 1834 on the San Francisco, a branch of the Gila River in western New Mexico, and died in captivity February 17, 1909. His real name was Goyathlay ("one who yawns"). In 1876 he and other Apaches fled to Mexico to avoid being moved to San Carlos, Ariz., but he was recaptured. In 1882 he left San Carlos on a raid into Sonora but surrendered to Gen. G. H. Crook in the Sierra Madre and settled on his fine farm at San Carlos. In 1884–85 he made a bloody raid through southern Arizona and New Mexico into Mexico, where in August, 1886, he and Nachi (his chief, son of Cochise) and their band of 340 were captured by General Miles and sent to Florida and finally to Fort Sill in Oklahoma. He died there Feb. 17, 1909 (Hodge, F. W., Handbook of American Indians: Bur. Am. Ethnology Bull. 30, p. 491, 1912).

New York and New England combined. Arizona is a region of vast plateaus, in larger part from 5,000 to 8,000 feet above sea level, numerous ridges and mountains, some of them reaching more than 12,000 feet, and many wide desert valleys. The highest point is San Francisco Peak, north of Flagstaff, elevation 12,611 feet; the lowest point is on the Colorado River below Yuma, about 70 feet. On account of its great width from north to south and its range in elevation the State presents wide diversity of climate, with extremes in the low hot regions near Yuma and the cold forested mountains in the north.

Although the agricultural resources of Arizona are not developed to their full possibility, even where water is available for irrigation, the farm products for 1929 were valued at $50,544,000 and for 1930 at $37,000,000. The area cultivated, most of it irrigated, was about 650,000 acres,[12] or less than 1 per cent of the area of the State. The number of farms in 1929 was 8,523. Of the total area, 10,526,627 acres, or 14½ per cent, is in farms or ranches, and their value in 1930, including buildings and machinery, was $194,644,470. Nearly 22,000 acres is in fruit trees. In 1929 the cultivated hay crop had a value of $5,745,444, and wheat and other grains $2,061,808. In 1930 cattle numbered 695,118, with large yield of dairy products, and sheep and goats numbered 1,630,853 and yielded nearly 6,200,000 pounds of wool and mohair, which sold for more than $1,600,000. Fruits of citrus and deciduous trees, a comparatively new source of income in Arizona, reached a value of nearly $2,000,000 in 1928. Cotton and corn are being more and more cultivated as new lands are brought under irrigation. In 1929 211,178 acres was in cotton, yielding 149,488 bales, valued at about $15,000,000. Some of the cotton is of the long-staple variety, averaging 1⅝ inches long, which is in great demand for automobile tires. This variety was developed from the Mitafifi stock brought from Egypt by the United States Department of Agriculture about 1900.

Arizona is second to California in the production of lettuce, especially the "Iceberg" variety, which yields two crops a year. Timber has been an important industry for 40 years, with a cut of 160,000,000 board feet in 1929, valued at nearly $5,000,000. The remaining timber, of which there is a vast area with a growth estimated by the United States Forest Service at over 14,000,000,000 board feet, is mostly in national forests, where it is cut under supervision and brings a good revenue to the United States.

Mining has always been the chief industry of the State, and it is estimated that 25 per cent of the adult population is connected with this industry. The total output up to 1929 had a value of about

12 These figures and the following statistics as to farming, livestock, and timber are taken from the reports of the Fifteenth Census of the United States.

$2,500,000,000, and $37,000,000 has been paid in dividends by certain large mines (Yearbook of Arizona, 1930). Copper is the chief product, coming mostly from mines at Bisbee, Jerome, Globe, Miami, and Ray. According to the United States Bureau of Mines, the total output of the State to the end of 1929 was 13,914,970,235 pounds, making it the largest copper-producing region of the world. Arizona now supplies 46 per cent of the United States output of copper and 22 per cent of the world's product, or slightly less than South America. Most other common metals are also produced. Many old mines have been abandoned, but new developments are constantly in progress. The Bureau of Mines states that the value of the principal metals produced by mines in Arizona in 1929 was about $158,433,300. Owing mainly to greatly reduced production, but partly to the lower price of most of the products, the value dropped to half of this amount in 1930 and to less than a quarter in 1931. In 1929 gold was mined to a value of about $4,217,000,[13] silver $3,875,000, copper (833,525,000 pounds) $149,200,000, lead $984,250, and zinc $156,800. The year 1929 was the most prosperous since 1918, and the sum paid in dividends that year was the largest on record, but in 1931 the gold output decreased to about $2,554,000, silver to about $915,500, and copper to about $33,000,000 (Bureau of Mines). Altogether the mines of Arizona have yielded profits in excess of $500,000,000 (Yearbook of Arizona, 1930). A large amount has been spent in prospecting and unprofitable mining.

According to the Yearbook of Arizona for 1930, the assessed valuation of property in Arizona in that year was $714,945,809. There are more than 2,500 miles of railroad lines in the State.

With a population of 435,573, according to the census of 1930, or 3.8 persons to the square mile, Arizona is one of the most thinly populated of our Western States. The increase in population from 1920 to 1930 was 30.3 per cent, or much greater than in most other States. According to the report of the Commissioner of the General Land Office for 1930–31, of its 72,838,400 acres there remains 14,366,400 acres of public land, but a very large part of this area is not suitable for agriculture. About half of this public land is not yet surveyed. Nearly 2,000 square miles is included in Indian reservations and national forests. The Commissioner of Indian Affairs, in his report for 1932, gives the Indian population as 48,162, or about 14 per cent of the total number of Indians in the United States. Of these nearly 25,000 are Navajos, nearly 6,000 Apaches, about 5,000 Pimas, and about 5,000 Papagos.

There are many indications of the presence of prehistoric aborigines in Arizona, for on plains, on mesas, and in the cliffs there are ruins of

[13] Gold has a fixed value of $20.671835 an ounce for "fine" or pure gold.

their habitations, some of them very old. However, it is believed that the number of people living in the region at any time may never have been great, for they moved from place to place, abandoning their communal or village dwellings. The early expeditions of the Spanish explorers found many pueblos, but they were widely scattered. It is probable that the first Spaniards to enter Arizona were the Franciscan friars, Juan de la Asunción, Juan de Olmeda, and Pedro Nadal, who made an exploration in 1538 from Mexico City "1,700 miles northwest to a broad, deep river" which they could not cross—perhaps the Colorado. In 1539 Marcos de Niza, another Franciscan friar, crossed southeastern Arizona from Sonora on the way to Zuñi. A year later De Niza led Francisco Vásquez de Coronado to Zuñi. Coronado had an advance escort of 50 horsemen, some natives and a group of friars, followed by his main army of 250 adventurers, including many Spaniards of high rank, and some 800 Indian allies. Two small parties from Coronado's expedition visited the Hopi pueblos, and they were also reached by Antonio de Espejo in 1583. Hernando de Alarcón explored the Gulf of California and lower Colorado River in 1540, and Juan de Oñate visited part of the same region in 1604–5. It was Oñate who in 1598 took possession of "all of the country north of New Spain" and called it Nuevo Méjico. In 1691 Eusebio Kino, a Jesuit priest, began his missionary work in Arizona, visiting settlements in the Santa Cruz, San Pedro, and Gila Valleys and supplying the Indians with livestock. He laid the foundation of the mission church of San Xavier at Bac, 9 miles south of Tucson (too-sown'), in 1700 and of San Gabriel at Guevavi, near Nogales, in 1701. He made numerous expeditions, reaching the Colorado River near Yuma in 1699 and again in 1700. He crossed the river below that place in November, 1701, and reached its mouth in March, 1702. The expedition of Father Jacobo Sedelmair in 1744 followed the Gila River (he'la) below Casa Grande and traversed the region west and south to Yuma, discovering the warm springs at Agua Caliente. Father Francisco Garcés, a Franciscan who labored for 12 years as a missionary to the Indians, made notable expeditions from San Xavier in 1768 to 1775 into southwestern Arizona and southern California. He was killed at Yuma in the Indian revolt of 1781. (See p. 237.)

After Mexico won her independence from Spain in 1822 the region made but little progress, and when in 1827 the order of expulsion against the Spanish caused most of the friars to leave, many of the little settlements were abandoned. The country north of the Gila River was ceded to the United States by the treaty of Guadalupe Hidalgo in 1848. Prior to that there were no American inhabitants in the territory. Most of the early visitors were prospectors, thousands crossing during the gold rush to California in 1849. After the Gadsden Purchase (see fig. 35), by which over 45,000 square miles south of the Gila River was acquired through an expenditure of $10,000,000 in 1854, several Governmental surveys were made across the region, mainly to find routes for railways. For a long time the principal access to Arizona was by water, ships from many ports coming into the Colorado River. Mail and passenger stages from the East (see pp. 97, 125) ran from 1857 to 1861 and again from 1867 till superseded by the railroads. The Southern Pacific line was constructed in 1879–80 from Yuma eastward to the Arizona State line, whence it was completed eastward to El Paso by the following year. (See p. 293.) From 1847 to 1860 many mines were opened and placers operated, more or less under protection of the Government. In 1860 the white population was less than 5,000. The outbreak of the Civil War and the withdrawal of troops gave the Apaches and white outlaws increased opportunity for depredations. Many settlers

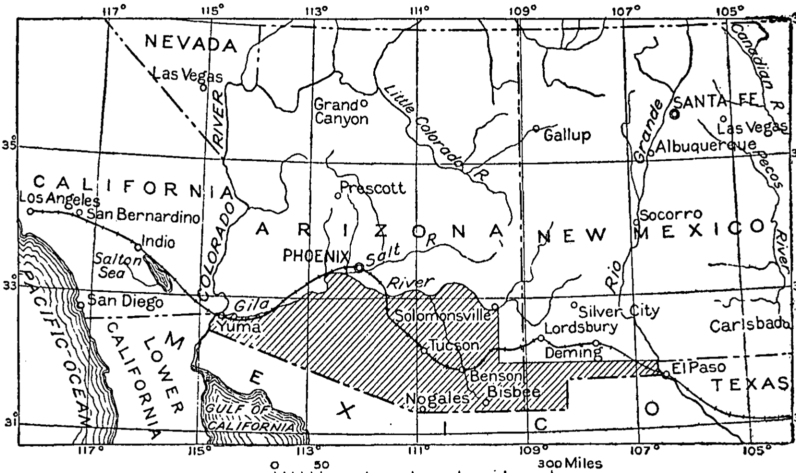


FIGURE 35.—Map showing the Gadsden Purchase (shaded area) acquired from Mexico in 1854 for $10,000,000

were killed at this time, most of the mining was discontinued, and nearly all who could do so left the country. A small band of people fortified themselves in Tucson, which was taken by the Confederates in 1862 and held until Union troops, known as the California Column, came from California. After the war also there was much bloodshed by Indians, who killed about 400 settlers and 150 soldiers in the interval from 1866 to 1886, when the Apaches were finally subjugated. The difficulties with these Indians greatly retarded the development of Arizona, for they kept out prospectors and settlers, interrupted travel, and frightened investors.

Originally Arizona was part of New Mexico, but on February 24, 1863, it was made a separate Territory of the United States and formally organized at Navajo Springs. Until 1871 it included the triangular area now constituting the south end of Nevada, named Pah-Ute County, which was separated by act of Congress in 1865.

The name Arizona is supposed to have been taken from Papago words that signify place of small springs. According to Cavat and Mora, however, it is derived from an ancient Pima name first applied to a mining camp in Sonora. It was used by the Spaniards as early as 1736. The capital has been successively at Fort Whipple, Prescott, Tucson, again at Prescott, and since 1889 at Phoenix. Statehood was attained February 14, 1912. The Southern Pacific Railroad was built through Arizona in 1880 and the Atlantic & Pacific (now a part of the Santa Fe system) in 1883. The first train entered the State at Yuma in September, 1877. (See p. 292.)

As the tracks wind down grade from Steins Pass, there are in view many plants of the curious-looking ocotillo (o-co-tee′yo), *Fouquieria splendens* (see pl. 41, *A*), which prefers the rocky soil of the foothills. It consists of a cluster of nearly straight, slender stems diverging upward, covered with thorns and bearing very small leaves during part of the year. In early summer each branch is tipped by a plume of bright-crimson flowers. A stalk thrust in the ground will usually grow, yet the wood is dry enough to make a torch. Mesquite occurs in places, especially along the arroyos and lower flats. The creosote bush (*Covillea tridentata*), named for the famous botanist F. V. Coville, is abundant here and throughout much of the desert region. It grows from 2 to 6 feet high and is rather widely spaced, after the habit of desert plants, so that the wide-spreading roots may gather the moisture from an ample area. For most of the year its leaves are covered with a resin that protects them against evaporation and also renders them very unpalatable to animals. Its small yellow flowers are conspicuous during part of the summer. The common name is due to a tarry odor given off when the plant is burned.

San Simon.

Elevation 3,613 feet.
Population 300.*
New Orleans 1,370 miles.

Ten miles beyond the State line is San Simon, the center of a small irrigation district using water from artesian wells. It is in the bottom of the wide San Simon Valley, which lies between the Peloncillo Mountains on the east, the Chiricahua and Dos Cabezas Range (dose ca-bay′sas) on the southwest, and the Pinaleño Mountains (pe-na-lane′yo) on the northwest. It is drained by San Simon Creek (usually dry), which empties into the Gila River 50 miles to the northwest. All the watercourses crossed by the north line of the Southern Pacific in Arizona empty into the Gila. This stream is one of the largest rivers of the Southwest and was the southern boundary of the United States before the Gadsden Purchase.

Where not irrigated the San Simon Valley is mostly a smooth plain covered with a sparse desert vegetation. It is underlain by a thick deposit of sand and gravel, which fortunately contains water available for wells. According to a report by A. T. Schwennesen the area in which artesian flows are obtained extends about 18 miles along the lower part of the San Simon Valley above and below San

Simon. Its width averages about 6 miles. There is also a small, narrow area of artesian flow at the San Simon Ciénega (se-ay′nay-ga) a few miles up the valley, and an extensive area in which water is obtained by pumped wells of moderate depth. Up to 1910 the region was a range for cattle belonging to widely separated ranches using water from shallow wells. Then the discovery of water in deeper beds under sufficient head to afford artesian flow brought many agriculturists, who have utilized the water for irrigation. In 1914 there were 127 flowing wells, mostly ranging in depth from 500 to 1,000 feet and yielding from 20 to 100 gallons a minute. It was estimated that at that time the total flow approximated 15 second-feet, or 11,000 acre-feet a year. Many nonflowing wells are now pumped. The quality of the water is excellent, most of it containing only from 250 to 380 parts per million of total solids. The moderate supply of water requires careful conservation, especially to avoid waste. The water occurs in gravel interbedded in light-colored clay and sand, which have been penetrated to a depth of 1,230 feet. These beds are overlain by a thick body of blue clay which holds the water down. The source of supply is rain that falls on the sides and upper part of the valley. The region has an arid climate, with a mean annual precipitation of less than 7 inches at San Simon; at Bowie, however, it is nearly 14 inches, a difference probably due to the proximity of the Dos Cabezas Mountains, in which the precipitation is estimated as near 20 inches. At Paradise, in the Chiricahua Mountains, it is 18 inches.

Originally the San Simon Valley was grassy, and the broad flats were covered with a coarse, high grass known as sacaton (sa-ca-tone′). With the extension of cattle grazing this was largely eaten out, but in rainy seasons the lower parts of the area had considerable small grass, and grama and other grasses grew in fair supply on the higher slopes. Since the advent of settlers erosion has cut deeply into the valley bottom, and many wide gullies and bare areas have resulted.

In the west slope of the Peloncillo Mountains, about 10 miles northeast of San Simon, are very small deposits of "saltpeter," or potassium nitrate, in rhyolite tuff, which have been prospected to some extent. It has been found, however, that the material is only a surface impregnation in crevices and under overhanging cliffs. Probably it has been formed through the action of bacteria on organic matter in places where the air has access and where the associated rock is sufficiently porous to permit the percolation of water, which would be concentrated by evaporation. The mineral occurs in this manner in many caves and places protected from the rain wash in the West and generally gives rise to the false hope that valuable nitrate deposits may be found.

The Chiricahua Mountains, which culminate in the peak known as Cochise Head (elevation 8,100 feet), are 15 miles south of San Simon.

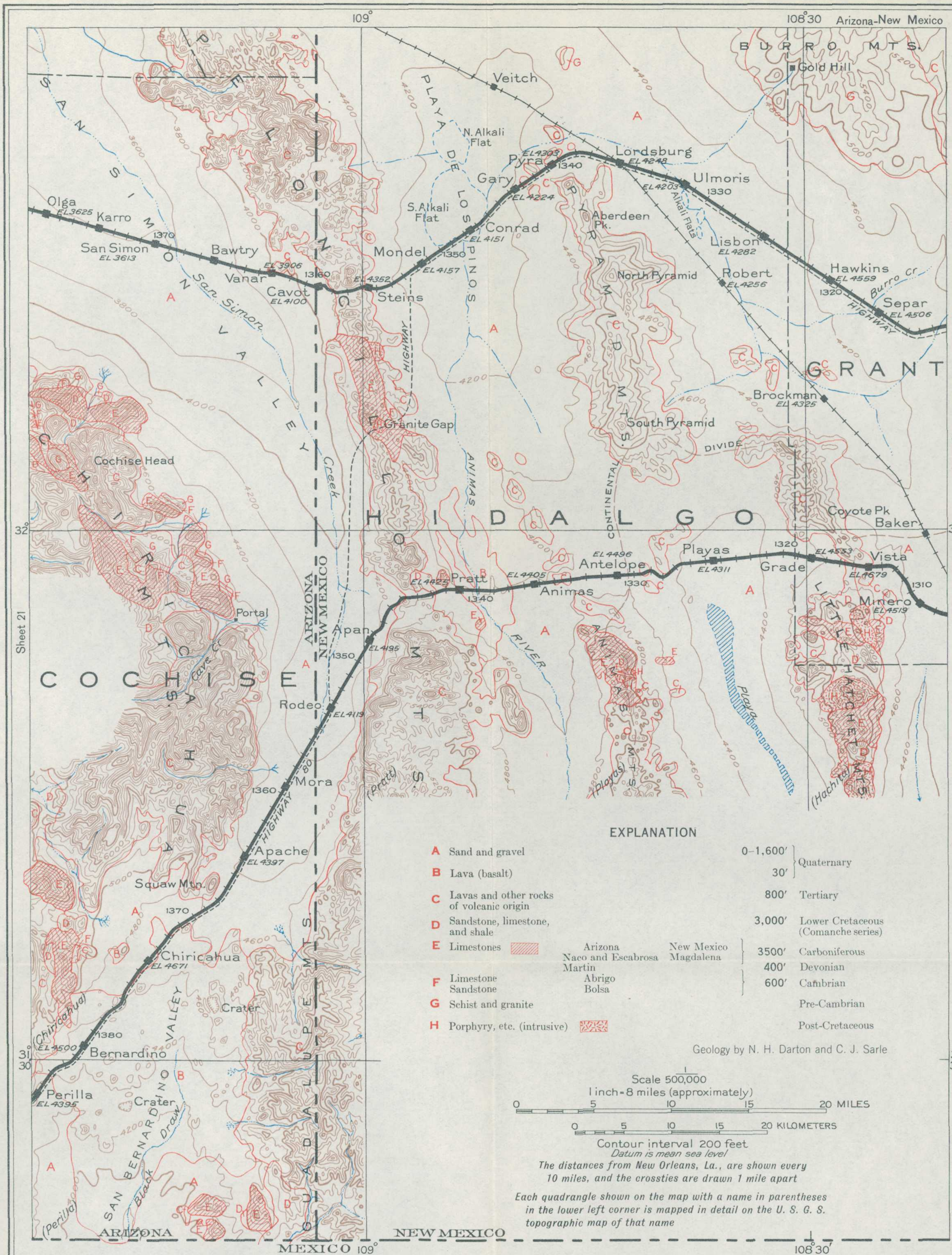
They consist largely of a thick succession of volcanic rocks of Tertiary age similar to those of the Peloncillo Mountains. Here, however, it may be seen that these rocks mantle an older mass of Paleozoic sandstones and limestones, in part overlain by sandstone, limestone, and shale of Lower Cretaceous age (Comanche series.)[14] In one area the intrusion of igneous rocks has changed the limestone to marble, which has been quarried to some extent. Blocks of this material lie along the railroad at Olga, a siding halfway between San Simon and Bowie. The deeper canyons in the mountains reveal a basement granite or schist of pre-Cambrian age. These mountains sustain a growth of pine on top and are part of the Coronado National Forest, which includes five timbered ranges in this general neighborhood. (Turn to sheet 21.)

About 15 miles southwest of San Simon is Apache Pass, a saddle of moderate height separating the Chiricahua Mountains from the Dos Cabezas Mountains and formerly the route of all emigrant travel, including the Butterfield stage line. This region was a favorite haunt of the Apache Indians because it was not far from their stronghold in the Dragoon Mountains. A fight near this pass in 1862 between these Indians and the California Column, the troops that came from California to restore Union supremacy, led to the establishment of Fort Bowie near the pass, which was long maintained as a military outpost.

West-southwest of San Simon are the Dos Cabezas, the culminating summit of the Dos Cabezas Mountains. They consist of two rounded knobs of granite close together and strongly suggesting "two heads," which the Spanish name means. This striking landmark is visible over a wide area in all directions.[15]

[14] The succession of strata in the Chiricahua Mountains is as follows: Sandstones and limestones (Comanche series); limestones of Carboniferous and Devonian age; slabby limestone (Abrigo) of Upper Cambrian age; and sandstone, in part quartzitic (Bolsa) of Upper Cambrian age. (See p. 175.) The general structure is anticlinal, but the arch is broken by faults. Porphyritic rocks of igneous origin cut some of the strata.

[15] The Dos Cabezas Mountains are a northwesterly continuation of the Chiricahua Mountains, from which they are separated by Apache Pass. They present the same Paleozoic strata as are exposed in the Chiricahua Mountains, but the amount of uplift increases to the northwest, and the pre-Cambrian granite and schist rise gradually and constitute the summits and higher slopes of the Dos Cabezas Range. The limestone under the Martin limestone (Devonian) has the character of the Abrigo beds at Bisbee, but Ordovician fossils occur in the upper beds. Most of this limestone here has slabby bedding, weathers to a light blue-gray color, and has brown reticulating markings of a supposed seaweed on many of the bedding planes. In these peculiarities it resembles the El Paso limestone of southwestern New Mexico. It is underlain by 200 feet of slabby limestone and sandstone on 150 feet of Bolsa quartzite (Cambrian), and the Bolsa lies on the pre-Cambrian schist and granite. Volcanic rocks such as cap the Chiricahua Mountains occur only in a small area of the southwest slope. The general structure is shown in Figure 36.



Topography: U. S. Geological Survey quadrangle maps

WILLIAMS & HEINTZ CO., WASH., D. C.

Bowie, a village in the San Simon Valley, is the junction point of the branch railroad that goes north down the valley to its mouth and thence down the valley of the Gila River, past the Coolidge Reservoir, and over a low divide to Globe (124 miles). This is the route of the Apache Trail trip to Phoenix described on page 207. The latest historical authorities appear satisfied that it was down this valley, as far as Solomonsville, that Fray Marcos de Niza and Coronado made their spectacular trips to Zuñi in 1539 and 1540. Bowie was named after Col. George W. Bowie, of the "California Column," who established Fort Bowie in Apache Pass.

Bowie.
Elevation 3,762½ feet.
Population 400.*
New Orleans 1,386 miles.

High on the south side of the Dos Cabezas Mountains is the mining settlement of Mascot (formerly reached by a branch railroad from Willcox), where considerable ore was mined some years ago. On the north slope of the range, southwest of Luzena siding (lu-say'na), there are many small placer workings from which for many years gold has been obtained, but the deposits are so irregular in location and variable in value that no attempt has been made to work them

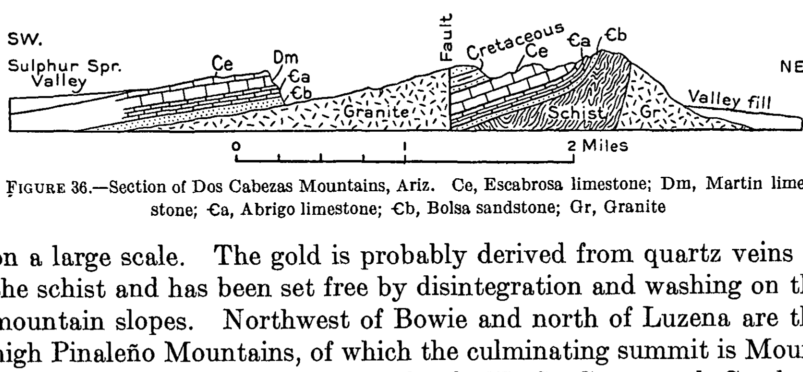


FIGURE 36.—Section of Dos Cabezas Mountains, Ariz. Ce, Escabrosa limestone; Dm, Martin limestone; Ꞓa, Abrigo limestone; Ꞓb, Bolsa sandstone; Gr, Granite

on a large scale. The gold is probably derived from quartz veins in the schist and has been set free by disintegration and washing on the mountain slopes. Northwest of Bowie and north of Luzena are the high Pinaleño Mountains, of which the culminating summit is Mount Graham, 10,720 feet above sea level (U. S. Coast and Geodetic Survey), about 30 miles distant. Mount Graham was named either for Maj. L. P. Graham, who led an expedition from Chihuahua to California in 1848, or for Lieut. Col. J. D. Graham, who acted on the United States and Mexico Boundary Survey Commission.

The Pinaleño Mountains consist mainly of massive gray granite, but in their south end is a flanking mass of volcanic rocks similar to those in the Peloncillo and Chiricahua Mountains and in many other ridges in New Mexico and Arizona. Outlying exposures of these rocks also appear not far north of the railroad near Luzena siding and at intervals west. As there is considerable pine timber in the Pinaleño Mountains, they are included in the Coronado National Forest

West from Luzena siding the railroad continues upgrade on the valley-fill deposits, which extend to and through a low, wide divide at the north end of the Dos Cabezas Mountains. This divide, known as

Railroad Pass, is at Raso siding, where an elevation of 4,376 feet is attained. A short distance south of this siding are mountain slopes of schist and granite, and at the divide there is a cut in gravel. The foot of the Pinaleño Mountains lies a few miles north, and Mount Graham is discernible in the distance. To the west is a short descent to Willcox, in Sulphur Spring Valley, across which the Winchester Mountains are visible. Sulphur Spring Valley was named from a sulphur spring at the foot of a small butte 20 miles south of Willcox. Established in 1880, Willcox was named for Gen. O. B. Willcox, at that time commander of the military department of Arizona and southern California (1878–82).

Willcox.

Elevation 4,166 feet.
Population 806.
New Orleans 1,410 miles.

Sulphur Spring Valley is a wide, nearly level-floored basin 130 miles long, with no outlet stream, which receives the drainage of a large area of surrounding slopes and mountains. In it there has been deposited a thick accumulation of sand, gravel, and loam. Much water passes underground in this material, and about Willcox and for some distance north there are scores of wells which obtain from this source an abundance of pure, soft water for irrigation and domestic use. The land is fertile and the irrigated areas yield various farm products, notably pink beans, and fruits. Willcox is one of the largest cattle-shipping points in Arizona and the outlet for many sheep and much wool and mohair. In the center of the basin is a large, shallow flat of about 40 square miles, of irregular shape, known as Willcox Playa. In times of rainfall this playa becomes a shallow lake, but in dry weather, which usually prevails, it presents a wide expanse of glistening salt, covered in places by ponds of saline water. Although there is little mineral matter in the run-off water from the mountains, it is all concentrated by evaporation in the central basin, of which the playa occupies the lowest part, and as this process has continued for many centuries considerable saline matter has accumulated. Sediments have been deposited at the same time, so that the basin now contains a thick succession of clay and silt and saline admixture. For a time this basin was occupied by a lake, which has been called Lake Cochise. It varied considerably in depth, but a zone of beach sands and sand dunes marks a shore line that persisted for a long period of inundation. Sand dunes of this old beach are conspicuous near Hado siding (ah′doe). Beyond this place is a broad flat of saline deposits on which, at times, considerable water is visible on each side of the embankment on which the railroad passes. The playa is only about 3 miles wide near the railroad but widens greatly to the east and south. Frequently there are striking mirages on this playa in which the great flat in the distance appears to be a huge lake with the buttes to the south rising as islands.

Pits dug in the valley floor near Willcox and Cochise have revealed bones of horses, elephants, camels, and bisons of early Pleistocene age.

These animals were probably mired in the soft mud at the edge of the prehistoric lake.

The desert valleys of San Simon and Sulphur Spring were inhabited by Indians of the agricultural class long before the advent of the Apaches. They had small settlements on the slopes near the foot of the mountains, mostly at places where the ground was occasionally flooded by summer downpours. Most homesteaders who have tried to live in such places have failed, but the Indians had the advantage of special drought-resisting varieties of corn, beans, and squash, which matured quickly when they had a little water, and their ability to piece out the ration with mesquite beans, sacaton seed, and animal food. Possibly there were many other plants that yielded food for them. Water supply was a serious problem, for in many places the water had to be brought from a great distance. Many potsherds indicate that they had plenty of vessels for the storage of food and water.

Cochise.
Elevation 4,231 feet.
Population 100.*
New Orleans 1,420 miles.

Cochise is a small village sustained mainly by ranches in the adjoining valley, and it is the junction point of the Arizona Eastern Railroad, which goes south through Sulphur Spring Valley to the mining settlements of Pearce (15 miles), Courtland, and Gleeson and the city of Douglas. (See p. 173.) At Pearce is the Commonwealth mine, which has been producing gold and other ore for the last 35 years. The production to 1922 is stated by the present owners to have been $20,000,000.

Northwest of Cochise is a prominent butte consisting mainly of limestone of Carboniferous age, on the southern extension of the axis of the Winchester Mountains.

The old Butterfield Overland Mail, having come through Apache Pass and crossed Sulphur Spring Valley some distance south of Willcox, passed near Cochise and through Dragoon Pass to the old stage station at Croton Spring, in the San Pedro Valley. Near Cochise the railroad has a moderate upgrade to reach Dragoon Pass, the gap between the Dragoon and Little Dragoon Mountains. In the Dragoon Mountains, which lie south of the railroad, is the celebrated canyon known as Cochise's Stronghold, where the wily Apache band under the leadership of Cochise took refuge when pursued. This handsome canyon, eroded out of red granite, has so narrow a mouth that it was easily defended and never taken. Gen. O. O. Howard was secretly conducted here by agents of Cochise for the conference which led to a treaty in 1872. (See p. 147.) The remains of Cochise are buried near the mouth of the canyon, but no white man has ever known the precise location. The stronghold, now often used as a picnic ground, can be easily reached by road from Cochise.

A short distance south of Manzoro siding is the old Golden Rule mine, formerly a producer of silver ore in moderate amount, from veins at or near the contact of an igneous intrusive mass (monzonite) with limestone of Abrigo to Martin age at the north end of the Dragoon Mountains. These mountains extend south from Dragoon Pass to and beyond the mining settlements of Courtland and Gleeson and contain many small mines and prospects. The general struc-

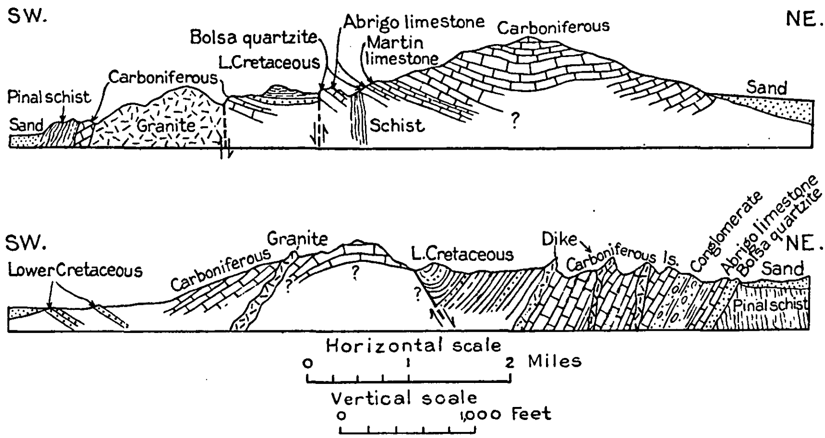


FIGURE 37.—Sections across the Dragoon Mountains, Ariz. Upper section, 3 to 6 miles southwest of the railroad; lower, 12 miles southwest of the railroad

ture of the northern and medial portions of this range is shown in Figure 37.[16]

Some of the limestone on the west slope of the central ridge has been altered to marble by igneous intrusions, and this rock has been quarried in small amount in the slopes 3 miles southeast of Dragoon. In the higher part of the limestone succession in the north end of the Dragoon Mountains is a member of red sandstone and much coarse limestone conglomerate containing boulders of limestone and sandstone.

Dragoon.
Elevation 4,614 feet.
Population 83.*
New Orleans 1,430 miles.

North of Dragoon are the high hills and ridges of the Little Dragoon Mountains, in which is situated the small mining settlement of Johnson, a copper producer for 45 years. The southern part of this range has a rough surface of knobs of granite, mostly of very coarse

[16] The Dragoon Mountains consist largely of post-Cretaceous granite, which cuts across the Pinal schist (Archean), Bolsa quartzite (Cambrian), Abrigo limestone (Cambrian), Martin limestone (Devonian), limestone of Carboniferous age, and sandstone and shale of Lower Cretaceous age. Small areas of Tertiary volcanic rocks occur among the ridges and on the flanks of the range. The strata are considerably hardened and mineralized by the heat of the igneous intrusions, and many large detached masses of the limestone are included in the granite. The eastward-dipping limestone succession in the north end of the range, with a thickness in excess of 2,000 feet, is mainly Naco limestone (Permian and Pennsylvanian). Abrigo limestone and the underlying Bolsa quartzite on Pinal schist are exposed in slopes 3 miles southeast of Dragoon station, with the relations shown in the upper section in Figure 37.

grain, possibly of pre-Cambrian age, although it resembles the younger intrusive granite of the Dragoon Mountains. This picturesque granite area is traversed by the highway northwest of Dragoon, where it presents an extraordinary variety of remarkable erosion forms, notably rounded masses. The rock contains large crystals of feldspar, which weather out conspicuously, and also veins of tungsten ore (wolframite and scheelite), which were mined during the World War.[17] Pre-Cambrian schist is also exposed, in places overlain by Bolsa quartzite, Abrigo and Martin formations, and limestones of Carboniferous age that constitute the crest of the high ridge just west of the mining camp and also a ridge on the east side of the valley, east of Johnson. The general features in this vicinity are shown in Figure 38. The Abrigo limestone consists mostly of slabby beds and includes considerable sandy shale. At the top is a sandy member, as

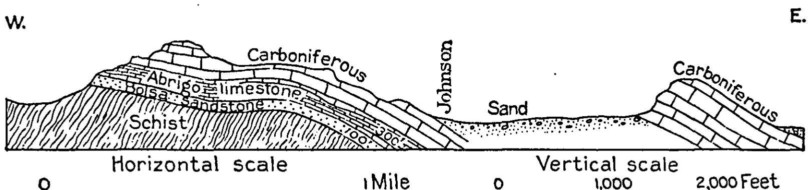


FIGURE 38.—Sketch section through the Johnson mining district, north of Dragoon station, Ariz.

in the Bisbee region. An outlier of this formation caps the ridge which is skirted by the railroad 4 miles southwest of Dragoon.

From Dragoon west there is a steep down grade into the deep valley of the San Pedro River (pay'dro). This depression is very different in character from the broad, high basin of Sulphur Spring Valley—a difference due to the presence of a vigorous stream which has cut a deep, wide trench into the thick body of old stream deposits that originally occupied the valley. The San Pedro River rises in Mexico and has many affluents from the Mule, Huachuca (wa-choo'ca), Whetstone, and other mountains. Ordinarily its flow is not large, but in times of heavy rainfall there are freshets which erode the soft valley deposits and carry a large volume of detritus to the Gila River. The railroad in its descent to Benson requires many long loops to diminish the grade, and there are numerous deep cuts through the materials of the valley fill. On this grade near and beyond Ochoa siding there are fine views of the Rincon Mountains (rin-cone') to the northwest and the Whetstone Mountains to the west. The Huachuca Mountains lie far to the south; to the southeast, in the Dragoon Mountains, the impregnable western wall of Cochise's Stronghold can

[17] Tungsten is used mostly for the filament in electric lights and for hardening steel, especially tool steel. A large proportion of the ore now used comes from China and Burma and only one-seventh from the United States. Tungsten ore also occurs in veins in granite on the east slope of the Whetstone Mountains southwest of Benson.

be seen. The granite cliffs of Cochise's Stronghold border a deep valley extending far into the Dragoon Mountains. Here the Apache Indians had a most useful hiding place, easily defended against every approach. Gerónimo fled here after his depredations and murders in Sulphur Spring Valley.

The valley-fill materials revealed in cuts, badlands, and deeply gullied slopes are mostly fine pale reddish-brown sand and loam with a few beds of coarser materials. The brownish loam predominates, with nodular layers and beds of harder sandstone projecting from it. The lower beds well exposed east of Benson are reddish clay. This succession is about 900 feet thick in the valley slopes, and several hundred feet additional is known to underlie the valley floor at Benson, although above and below that place some of the underlying granite and schist are bared near the river. The sands and clays are deposits of former streams and lakes, which occupied the valley for a long time. They lie nearly horizontal near the center of the valley and grade laterally into coarse deposits (Gila conglomerate) consisting of detritus from the adjoining mountain slopes and for the most part considerably tilted. In the clays have been found numerous remains of animals such as horses, elephants, mastodons, camels, deer, llamas, carnivores, various rodents, several reptiles, the tortoise *Glyptotherium*, and several species of birds which have been described by J. W. Gidley. Many are new species, and some are South American types. They are regarded as of late Pliocene age and indicate a warm, moist climate, probably subtropical. This faunal assemblage is very different from the present one and has been extinct for many thousands of years.

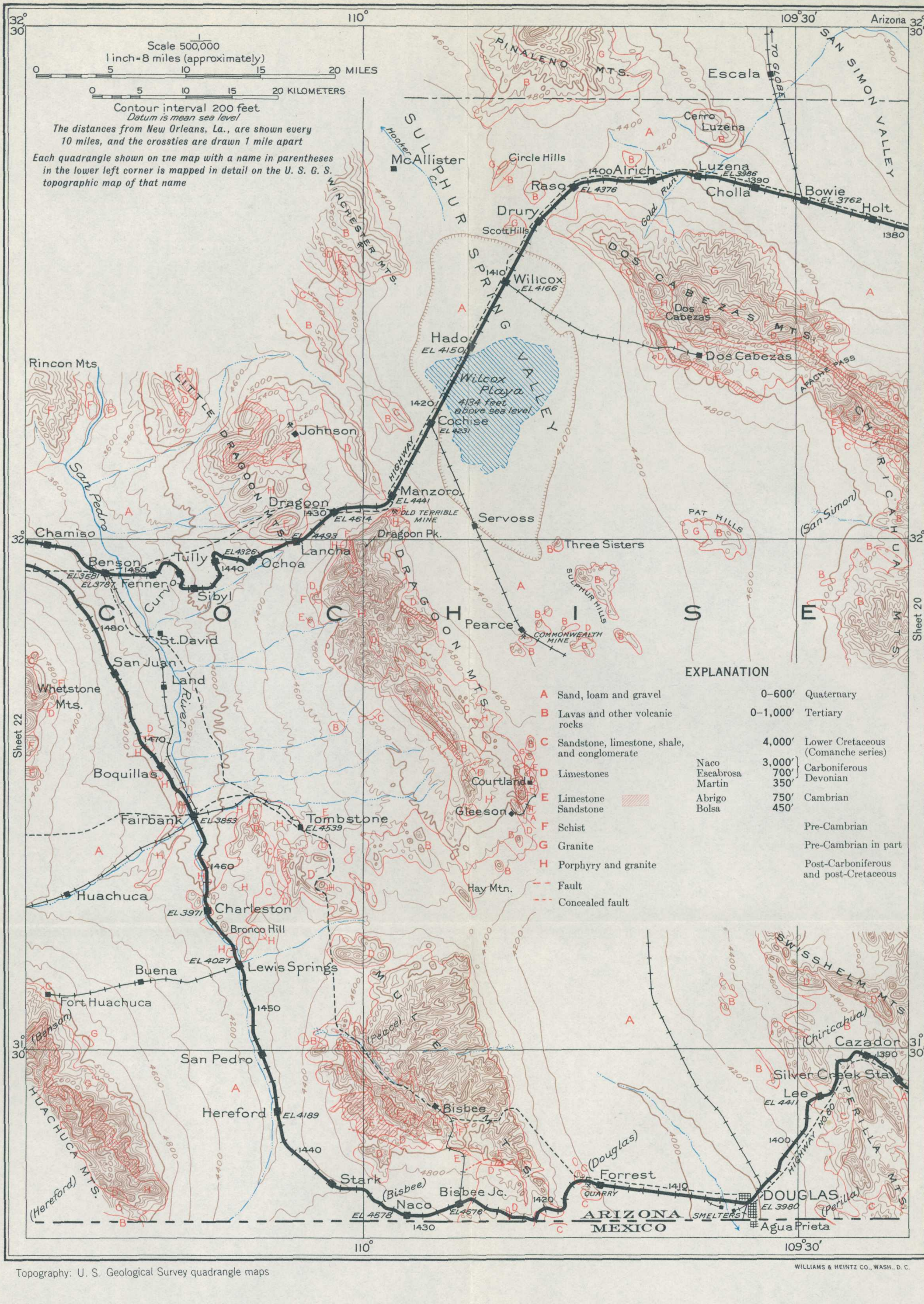
In the fine-grained deposits in the southern part of the valley are deposits of gypsum and thick bodies of diatomaceous earth consisting largely of diatoms, minute siliceous skeletons, mixed with volcanic ash.

The San Pedro River, which is crossed a short distance east of Benson, flows into the Gila River near Winkleman, nearly 100 miles to the northwest. It is a small stream when not in freshet but furnishes water for irrigation at several places, notably the old Mormon settlement of St. David, a few miles above Benson, established in 1878. Here also was the first artesian district in Arizona; the water is obtained from wells of moderate depth in the valley fill.

Benson.
Elevation 3,581 feet.
Population 925.
New Orleans 1,452 miles.

Benson is a small commercial center and junction point for a branch railroad up the valley to connect at Fairbank with branches to Tombstone and Patagonia. The Southern Pacific south line (by way of Douglas) is on the bench 3 miles west of Benson. In the San Pedro Valley are many ruins of dwellings and pottery and implements of aborigines who long antedated the advent of the Spanish explorers from Mexico. According to Sauer and Brand [18] some of the settlements were of considerable extent.

[18] California Univ. Pubs. in Geography, vol. 3, No. 7, 1930.


Scale 1/500,000
1 inch=8 miles (approximately)
0 5 10 15 20 MILES
0 5 10 15 20 KILOMETERS
Contour interval 200 feet
Datum is mean sea level
The distances from New Orleans, La., are shown every 10 miles, and the crossties are drawn 1 mile apart
Each quadrangle shown on the map with a name in parentheses in the lower left corner is mapped in detail on the U. S. G. S. topographic map of that name
EXPLANATION
A Sand, loam and gravel 0–600′ Quaternary
B Lavas and other volcanic rocks 0–1,000′ Tertiary
C Sandstone, limestone, shale, and conglomerate 4,000′ Lower Cretaceous (Comanche series)
D Limestones Naco 3,000′ Escabrosa 700′ Carboniferous Martin 350′ Devonian
E Limestone Sandstone Abrigo 750′ Bolsa 450′ Cambrian
F Schist Pre-Cambrian
G Granite Pre-Cambrian in part
H Porphyry and granite Post-Carboniferous and post-Cretaceous
Fault
Concealed fault
C O C H I S E
SULPHUR SPRING VALLEY
PINALENO MTS.
SAN SIMON VALLEY
DOS CABEZAS MTS.
CHIRICAHUA MTS.
DRAGOON MTS.
LITTLE DRAGOON MTS.
WINCHESTER MTS.
MULE MTS.
HUACHUCA MTS.
SWISSHELM MTS.
PERILLA MTS.
Wilcox Playa 4134 feet above sea level
Escala
Bowie
Holt
Luzena
Cholla
Alrich
Raso
Drury
Wilcox
Hado
Cochise
Manzoro
Dragoon
Lancha
Ochoa
Tully
Benson
Chamiso
Fenner
Curvo
Sibyl
St. David
San Juan
Land
Boquillas
Fairbank
Tombstone
Huachuca
Charleston
Bronco Hill
Lewis Springs
Buena
Fort Huachuca
San Pedro
Hereford
Stark
Naco
Bisbee Jc.
Bisbee
Forrest
DOUGLAS
Agua Prieta
Lee
Silver Creek Sta.
Cazador
Pearce
Courtland
Gleeson
Servoss
Johnson
McAllister
Dos Cabezas
Three Sisters
Circle Hills
Cerro Luzena
Scott Hills
Dragoon Pk.
Hay Mtn.
Rincon Mts
Whetstone Mts.
PAT HILLS
SULPHUR HILLS
APACHE PASS
OLD TERRIBLE MINE
COMMONWEALTH MINE
SMELTERS
QUARRY
HIGHWAY
HIGHWAY NO. 80
San Pedro River
Hooker C.
Gold Run
(Benson)
(Hereford)
(Bisbee)
(Douglas)
(Peace)
(Chiricahua)
(San Simon)
(Perilla)
ARIZONA
MEXICO
Arizona
Sheet 22
Sheet 20
110°
109°30′
32°
32° 30′
31° 30′

The San Pedro River was the Rio Nexpa of the era when De Niza and Coronado made their expedition from Mexico to the Indian pueblo of Zuñi in quest of the somewhat legendary "Seven Cities of Cibola." It seems probable that their route led from Mexico down the San Pedro Valley as far as the site of Benson, thence eastward over Dragoon Pass and Railroad Pass to the San Simon Valley, which it followed northward to its junction with the Gila River. A hundred and fifty years later Padre Kino made an exploration with Lieutenant Mange and Captain Bernal along the San Pedro from Quibure northward along the base of the Rincon Mountains to its junction with the Gila and thence to Casa Grande and beyond. The valley was fertile and irrigated, and the Indians were industrious, raising maize, frijoles, calabashes, and cotton. There were 14 villages and 2,000 Indians, all very friendly to the friar. This line of travel from Benson north was followed by the road from El Paso to Yuma for which Congress appropriated $200,000 in 1857; Bancroft gives it as the route of the Butterfield stages, but Hafen includes Tucson in their itinerary. The road previously opened by Colonel Cooke and the Mormon Battalion left the San Pedro Valley at Benson, turning west to Tucson, the course now followed by the railroad. It leads through the broad divide between the Whetstone [19] and Rincon Mountains at Mescal. On this rather steep climb there are many cuts through the valley fill and extensive badland slopes, and as the top of the grade is approached there are excellent views of the Rincon Mountains to the north and the Whetstone Mountains to the southwest. The Rincon Mountains consist of pre-Cambrian schist with

[19] The Whetstone Mountains consist of an uplifted block of pre-Cambrian granite overlain by Paleozoic limestones and Cretaceous rocks, but as in most mountains of this character rising out of alluvial valleys, the structural relations at the sides and ends are not revealed. Granite constitutes the foothills and peaks on the northeast end of the range except in a small skirting ridge of Lower Cretaceous (Comanche) sandstone and shale lying about 5 miles south of the railroad. A small area of Pinal schist appears on the east slope, faulted against Carboniferous limestone, and a thick mass of Cretaceous strata constitutes the southern third of the range, which is not visible from the railroad. Figure 39 shows the principal features in the northwestern part of the range. The succession, which is typical for southern Arizona, has basal quartzite (Bolsa) of Upper Cambrian age, overlain by Abrigo slabby limestone (Cambrian) which closely resembles the El Paso and Longfellow limestones. The Abrigo weathers to a light gray-blue color with brown reticulating stains on the slabs, probably due to a seaweed of early Paleozoic time. In the lower part are many layers of sandstone and sandy shale. The Martin limestone, next above, contains numerous fossils of Devonian age, some of them finely preserved, and the overlying limestones, which are 1,000 feet or more thick in the center of the mountain, include representatives of the Escabrosa and Naco carrying many fossils of Carboniferous age. The high southern summit, known as Granite Peak, appears to be a mass of intrusive porphyry cutting Cretaceous strata.

massive platy structure that gives it the appearance of limestone in some lights. Rincon Peak, a high summit in the southern part of the range, is 8,465 feet above sea level.

The Whetstone Mountains are in full view to the south from points near Mescal. The higher parts of the Rincon, Whetstone, and other mountains to the north and south are included in the Coronado National Forest so that their pine timber may be conserved.

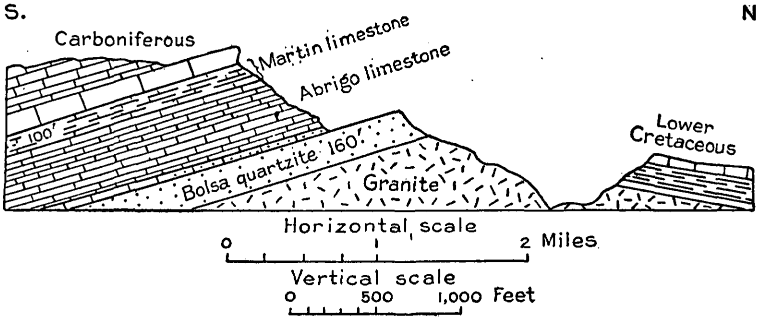


FIGURE 39.—Sketch section across the northwest end of the Whetstone Mountains, Ariz.

SOUTH LINE FROM EL PASO, TEX., TO MESCAL, ARIZ.

Several trains go to Tucson (see sheet 18, opposite p. 136) over the former El Paso & Southwestern Railroad, which has a more southerly route than the original Southern Pacific line by way of Deming and Lordsburg and joins the north line at Mescal, 40 miles east of Tucson. It parallels the north line for the first few miles out of El Paso, crossing the Rio Grande in the western part of the city, into the southern part of New Mexico, skirting the north side of the Cerro de Muleros (moo-lay'ros); it diverges from the north line beyond Anapra siding. (See p. 132.) Just west of the Rio Grande it passes through an area of Cretaceous strata adjoining the intrusive mass of the Cerro de Muleros, which makes the south or Mexican side of the "pass" from which El Paso is named. The strata exposed are mostly dark shale of upper Washita age in which there are long cuts, beginning a few rods beyond the west end of the bridge and extending west to and beyond Bowen, a siding at the west end of a tunnel through the shale. Below the shale are limestones of Washita and Fredericksburg age (Comanche series), the latter extensively exposed in the cement quarries a short distance north of the river bridge. (See also p. 131.) (See fig. 40.) In the upper part of the dark shale are sandy beds containing "*Nodosaria*" and other forms indicating Del Rio age. It is overlain by a hard sandstone probably basal Upper Cretaceous (Eagle Ford), which is conspicuous on the ridge just west of the railroad near the tunnel and crosses the railroad half a mile beyond Bowen. This sandstone

Bowen.
Elevation 3,845 feet.
Population 20.*
New Orleans 1,193 miles.

is overlain by white massive limestone with many large Exogyras of Upper Cretaceous age.

Not far beyond this place the tracks approach those of the north line, which they closely parallel to Anapra siding. Here begins the long climb to the top of the high terrace plain that borders the Rio Grande Valley and extends far westward across southwestern New Mexico. (See p. 133.) On the ascent there are fine views to the north up the Rio Grande Valley, to the east to the long west slope of the Franklin Mountains with its succession of westward-dipping strata, and to the south to high ridges in Mexico. On this upgrade there are many cuts which afford excellent exposures of the sand and gravel making up the desert plain, the top of which is reached near Mastodon siding, so named because the remains of a mastodon were excavated in the slope on the northeast. This great elephant was formerly abundant over a large part of the present United States, and his remains,

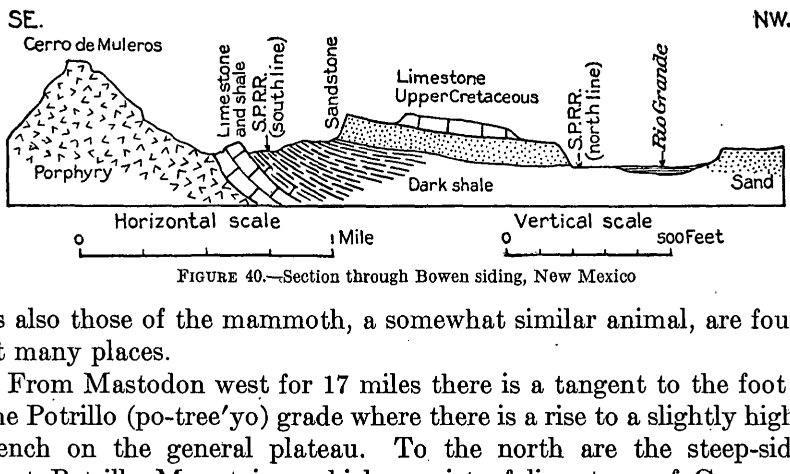


FIGURE 40.—Section through Bowen siding, New Mexico

as also those of the mammoth, a somewhat similar animal, are found at many places.

From Mastodon west for 17 miles there is a tangent to the foot of the Potrillo (po-tree'yo) grade where there is a rise to a slightly higher bench on the general plateau. To the north are the steep-sided East Potrillo Mountains, which consist of limestone of Comanche (Lower Cretaceous) age.[20]

From Potrillo siding west there is a down grade to Mount Riley siding, which lies south of Mount Riley. This very prominent volcanic mass, just west of the north end of the East Potrillo Mountains, was apparently a vent from which lavas were ejected in Tertiary time. To the west are broad recent lava fields of the West Potrillo Mountains, with many craters and cinder cones, some of large size. Lava flows from these vents extend in various directions, some of them being traversed by the railroad from a point 2 miles west of Mount Riley siding to their western margin, about 15 miles

Mount Riley.
Elevation 4,109 feet.
Population 40.*
New Orleans 1,226 miles.

[20] This limestone contains *Caprina occidentalis*, *Trigonia* sp., and *Actaeonella dolium*, a Fredericksburg fauna determined by T. W. Stanton.

west of that place. Several large fresh-looking cinder cones are plainly visible not far north of the railroad. West of the lava fields there are knobs of igneous rocks on both sides of the track, but they are mostly of the older period of eruption.

At intervals during Tertiary and Quaternary time there was great volcanic activity in many parts of the West, and in southwestern New Mexico large areas were covered by lavas in both periods. At numerous vents the outflow of lava was followed by an outburst of cinders and ash, which were thrown into the air and, settling back about the vent, formed a cone, generally having a central crater. The building of these cinder cones therefore usually marked the last stage of activity of the volcano, but in some places a later gush of lava issued from the side or base of the cone. The lava contained a vast volume of steam, for much of it is highly porous, or vesicular, owing to the expansion of the steam in the lava as it spread over the surface. The cinder consists of lava filled with small steam holes, so that most of it is completely porous or "pumiceous." In the cinder of the cones are usually embedded masses of compact lava, probably thrown out as bombs. These vary in form from balls to elongated and irregular shapes, mostly with smooth surfaces, such as might be expected in molten material ejected from a vent. In places there are flattened masses of lava several yards in extent, in part twisted around some of the cinders in which they are inclosed.

On approaching Arena siding (turn to sheet 19) the railroad descends nearly 200 feet into a wide, smooth-surfaced basin, or desert, which extends to Columbus and beyond. It slopes southward into Mexico and is occupied by Palomas Arroyo, a dry wash which is crossed 2 miles east of Columbus. This arroyo leads south into Palomas Lake, in Mexico, a water body due to springs known as Ojo de las Adjuntas (o'ho day las ad-hoon'tas), which come up in the valley bottom about 2 miles south of the international boundary.

Columbus.
Elevation 4,058 feet.
Population 391.
New Orleans 1,262 miles.

Columbus is a commercial center for agricultural and stock interests in the southern part of Luna County. A considerable area in the Palomas Valley north of Columbus is irrigated from wells which draw water from a widespread underflow contained in the gravel and sand that underlie the desert plain. Columbus is on a main road from Mexico and has a custom house and at times has had an encampment of United States troops. It was the scene of a noted raid by the Mexican outlaw Pancho Villa in 1915 and has witnessed many border episodes of greater or less importance.

About 20 miles north of Columbus are the Florida Mountains, the south end of which is plainly visible. This range is described on page 139. To the northwest are the Tres Hermanas Mountains (trace air-mah'nas, Spanish for three sisters), named from the three prominent conical peaks in the north end. The main feature of this range is a large intrusion of quartz monzonite porphyry which uplifts limestones of Permian age. There are also some masses of eruptive rocks of Tertiary age. Zinc ore has been produced in considerable amount from mines in the altered limestone near the porphyry contacts. Some of the geologic relations are shown in Figure 41. In the ridges north of Columbus a small amount of onyx was quarried at one time.

From Columbus west the railroad continues across the great plain of valley fill and passes around the south end of the Tres Hermanas Mountains through Mimbres siding. Beyond Mimbres two small lava fields are crossed, apparently the product of rather recent

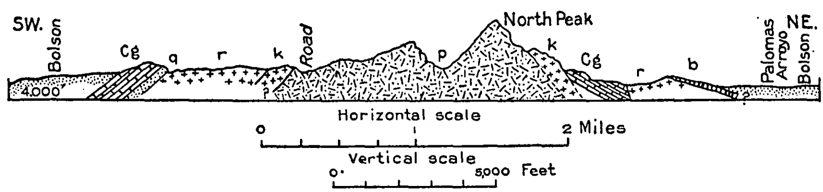


FIGURE 41.—Section across Tres Hermanas Mountains, Luna County, N. Mex. Cg, Gym limestone (Permian); p, porphyry; r, rhyolite; b, basalt; q, quartzite; k, keratophyre

eruptions. To the southwest are high mountains in the State of Chihuahua, Mexico.

Hermanas.
Elevation 4,453 feet.
Population 80.*
New Orleans 1,281 miles.

Hermanas is in the entrance to a low gap between the Carrizalillo Hills (ca-rree-sa-lee′yo) on the south and the Cedar Grove Mountains, a ridge which extends southeastward across the southwest corner of Luna County.[21] Two miles beyond Hermanas are the Carrizalillo Springs, a very good example of underflow water brought to the surface by a ledge of hard volcanic rock which here crosses the valley. To the west is a wide desert valley draining south into the great basin of Lake Guzman, in Mexico. The international

[21] This ridge consists mainly of a succession of thin sheets of latite and other volcanic rocks of Tertiary age, dipping to the northeast at low angles. A basal agglomerate crops out along the southern foot of the summit. The latite continues past Carrizalillo Springs and also constitutes an outlying front ridge south of Hermanas station. Locally it is underlain by andesite. Next above the latite is 600 feet or more of agglomerate with included sheets of coarse pink rhyolite and minor flows of other high-colored lavas (andesite, trachyte, and latite) overlain locally by a thin sheet of fine-grained dark-gray keratophyre, a lava rich in soda and carrying little or no quartz. A ridge parallel to the main Cedar Grove Mountains, extending northwest from Hermanas for about 16 miles, consists of a thick sheet of dark lava (basalt) dipping northeast and lying on tuffs and other fragmental volcanic deposits. Basalt also occurs at other points in the vicinity of the mountains, where it appears to have been the product of the latest eruption. The southeastern part of the Carrizalillo Hills shows sheets of rhyolite tuff and agglomerate, dipping east and somewhat faulted. This complex succession of volcanic products indicates a remarkable variation in sources of eruption in a relatively short period of geologic time.

boundary is about 2 miles south of the tracks near Savoya siding. To the southeast of this siding is a high volcanic range in Mexico, a southern extension of the Carrizalillo Hills. Far to the southwest is the Sierra Boca Grande, also in Mexico.

Victorio.

Elevation 4,576 feet.
New Orleans 1,294 miles.

Near Victorio siding (named from the Apache chief referred to on p. 147), which is in the middle of the valley, the rounded slopes of the Cedar Grove Mountains extend along the north side of the valley, and the more rugged outlines of the Sierra Rica rise prominently to the southwest.[22] About 1½ miles west of Continental siding there is a sign reading "Continental Divide," but this is a mistake, as the basin of Hachita Creek, to the west, empties into the Rio Casas Grandes in Mexico, which, like other streams east to Arena, drains into Lake Guzman. This is, however, the highest point on the railroad west of the Rio Grande, being 4,745 feet above sea level. The Continental Divide is crossed 20 miles or so farther west. (See p. 168.) From this sign west there is a down grade to Hachita (ah-chee'tah). North of the track on this grade is a long, narrow ridge capped by lava (basalt), which probably originally flowed down a valley and protected the area which it covered, while the adjoining surface was being eroded to a lower level. This is an interesting example of an old stream bed at a higher level than the new ones.

The Apache Hills, south of the railroad, consist mainly of intrusive quartz porphyry overlain by Tertiary volcanic rocks to the north and in contact with limestones of Comanche and probably Magdalena age to the south. There are several mines and prospects in the range; the largest is the Apache mine, which has produced considerable silver ore.

Hachita.

Elevation 4,515 feet.
Population 200.*
New Orleans 1,305 miles.

Hachita, in the broad Hachita Valley, is a small settlement, railroad junction, and headquarters for mining interests in the adjoining mountains. Several of the mines in the general region have had prosperity, and some are believed to hold considerable promise. The most productive mines are in the Sylvanite district, in the Little Hatchet Mountains, about 10 miles southwest of Hachita. (See sheet 20.)

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[22] The Sierra Rica consists largely of blue-gray limestone of Comanche age, in part massive and in part thin bedded. The strata have a general dip of 4°–5° N. in most of the area, but to the south they bend over a low anticline with west-east axis which passes through a small gap a quarter of a mile north of boundary stone 39. These rocks contain Trinity fossils, but ledges in outlying buttes to the east and probably separated by a fault contain Exogyras of Washita age. The western part of the Sierra Rica consists of limestone of Pennsylvanian (Magdalena) age, which in outlying buttes to the west is overlain by gray quartzite of Comanche age; this rock is also conspicuous in a small ridge 10 miles due south of Hachita. A mile east of boundary stone 39 there

South of the Little Hatchet Mountains [23] the much higher Hatchet Mountains are prominently in view, culminating in Big Hatchet Peak, 8,366 feet above sea level. They are of special geologic interest because they present an extensive succession of strata from Carboniferous to Cambrian lying on a floor of pre-Cambrian granite. The section in Figure 42 shows some of the relations. In the southwestern part of this range are thick beds of limestone, sandstone, and shale of Comanche age containing many characteristic fossils.

West from Hachita the railroad climbs a moderate grade of about 150 feet to reach the pass at the north end of the Little Hatchet Mountains. On the northern slope of these mountains near the railroad there are scattered exposures of dark shale of Comanche age. The ridge north of the railroad, of which Coyote Peak is the culminating summit, appears to consist mainly of Tertiary eruptive rocks.

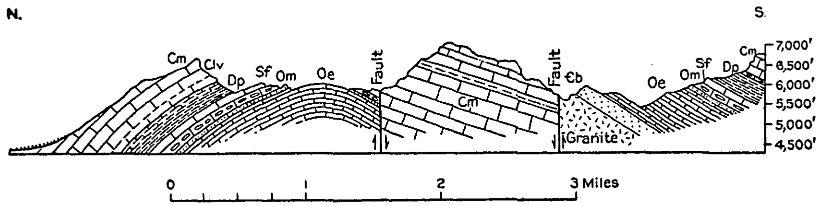

FIGURE 42.—Section across the north end of the Hatchet Mountains 20 miles south of Hachita, N. Mex. Єb, Bliss sandstone (Cambrian); Oe, El Paso limestone (Ordovician); Om, Montoya limestone (Ordovician); Sf, Fusselman limestone (Silurian); Dp, Percha shale (Devonian); Clv, Lake Valley limestone? (probably Mississippian); Cm, limestones of Magdalena group (Pennsylvanian)

At its north end is a westward-trending ridge known as Quartzite Mountain, consisting of quartzites of Comanche age. A small but prominent butte a short distance north of this ridge is made up of limestone of the Magdalena group.

West from Vista siding the railroad descends 368 feet into a broad basin with a long, narrow lake bed or "playa" in its bottom. In wet seasons this basin is occupied by water, but usually the northern edge of the lake is some distance south of the railroad. At a time not very remote geologically a larger lake existed in this basin long enough for

is a mineral vein associated with a quartzite (probably of Trinity age) which yielded considerable silver-lead ore at the International mine, long since abandoned.

[23] The Little Hatchet Mountains present a considerable variety of rocks and complex geologic relations. The south end of the range is granite, which, however, may be of post-Carboniferous age, and this rock is exposed prominently in Granite Pass, 15 miles southwest of Hachita. Next north of that gap are ledges of sandy shale of Comanche age cut by a large granite dike. The higher central part of the range consists of a thick succession of limestones of the Magdalena group (Pennsylvanian) dipping southwestward and cut off to the north by a large mass of porphyry. In the northern part of the range are many prominent buttes and ridges of sandstone, shale, and limestone of Comanche age and several large masses of intrusive rock; in the vicinity of the Old Hachita camp limestone of the Magdalena group is exposed.

beaches and other shore features to develop. Its depth was about 40 feet. The lowest point on the margin of this basin is at Hatchet Gap which leads into the valley of Hatchet Creek. The fill in Playas Valley is probably very thick, and nothing is known of the configuration of its bedrock floor. An 836-foot well near its center was entirely in loam, sand, and gravel. These deposits contain considerable water, which is pumped for stock and domestic use and to a small extent for irrigation. At a ranch about 25 miles south of the railroad there is an artesian well yielding about 5 gallons a minute from a depth of 102 feet.

Southwest of the Playas Valley are the Animas Mountains,[24] a long rugged ridge consisting largely of lavas of Tertiary age in widespread sheets considerably flexed and faulted. In their higher parts is an extensive pine forest included in the Coronado National Forest. The Continental Divide is crossed on the inconspicuous summit a few miles west of Playas siding, at an elevation of about 4,515 feet. To the west of this point the drainage flows into the Animas River, which empties into the playas west of Lordsburg. These playas, on the rare occasions when they overflow, drain into the Gila River, which empties into the Colorado River and thus into the Gulf of California.

Playas.
Elevation 4,311 feet.
Population 20.*
New Orleans 1,325 miles.

The detached ridges near the railroad between Antelope and Animas sidings are formed by Tertiary lavas. In this region there are fine views of the distant mountains, notably the Hatchet Mountains, 25 miles southeast. To the north are the Pyramid Mountains, which end just south of Lordsburg, on the north line of the Southern Pacific Railroad. According to Sauer and Brand [25] remains of very old Indian settlements have been unearthed in the Animas Valley, and there is evidence that crops were raised on some of the larger flats, doubtless by the use of flood waters. One notable settlement, which covered 60 acres or more, was at a large spring west of Animas, which was dried up by the earthquake of 1887. Many types of pottery and other utensils were found in the vicinity.

Animas.
Elevation 4,405 feet.
New Orleans 1,336 miles.

There are ranches scattered along Animas Valley which obtain water from wells in the valley fill. Some water, mostly pumped by gasoline engines, is used for irrigation.

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[24] On the central eastern slope of this range, southeast of a peak called Gillespie Mountain, limestone with Comanche fossils (possibly reworked) is extensively exposed; much if not all of it, however, is a conglomerate, and the materials may have been derived from near-by ledges of Comanche age. The ridges constituting the north end of the range 10 miles southwest of Playas siding consist largely of limestone of the Magdalena group (Carboniferous) and quartzite and shale of Comanche age. These strata are cut by large masses of porphyry which have been forced up in a molten condition.

[25] California Univ. Pubs. in Geography, vol. 73, No. 7, 1930.

Between Animas and Pratt sidings the railroad crosses a sheet of black scoriaceous basalt, a local lava flow of relatively recent age. Several low cinder cones mark vents through which the lava reached the surface. About 2 miles west of Pratt sandstone of Comanche (Lower Cretaceous) age constitutes a ridge extending for a mile or more along the east slope of the mountain just north of the railroad, and a short distance northeast of this ridge, or about 1 mile northwest of Pratt, is a conical butte of limestone of the Magdalena group.

Pratt.
Elevation 4,425 feet.
New Orleans 1,341 miles.

West of these features the railroad passes through Antelope Pass, a deep gap in the Peloncillo Mountains, and descends about 450 feet into the San Simon Valley, which drains into the Gila River. This mountain range extends for about 100 miles along the southwestern margin of New Mexico and consists mainly of Tertiary lava flows similar to those constituting the Animas Mountains and many other ranges, in a thick succession which is considerably flexed and faulted. Heavy beds of massive lava [26] and tuff lying nearly horizontal are well exposed on the north side of the gap. There are also necks and craters which were sources of outflow, but the region has been so deeply eroded since the time of eruption that the volcanic history is difficult to decipher.

About 12 miles north of Antelope Gap is Granite Gap, through which highway 80 crosses the Peloncillo Mountains in a low pass. Here the rocks underlying the Tertiary succession are revealed rising in a large mound in the center of the range.[27]

Beyond Antelope Gap the railroad bends southward and ascends the broad alluvial valley of San Simon Creek in order to pass around the south end of the Chiricahua Mountains. This high rugged range, rising grandly to the west of the railroad, presents an intricate mass of high peaks and a steep mountain front deeply notched by canyons. The higher part of the range is made up of a thick succession of lava flows which lie on an irregular floor of Paleozoic and Mesozoic limestones, sandstones, and shales. There are many faults, flexures, overlaps, and other features that have not been mapped

Rodeo.
Elevation, 4,119 feet.
Population, 160.*
New Orleans, 1,353 miles.

[26] Rhyolite with phenocrysts of quartz and orthoclase, as determined by C. S. Ross, of the U. S. Geological Survey.

[27] The El Paso limestone, here exposed, presents the same features as in the Franklin Mountains, near El Paso, but is much thinner. A massive dark limestone 30 feet thick strongly suggests the Fusselman. It is overlain by 100 feet of dark shale, probably Percha (Devonian), which is capped by limestones similar to the Escabrosa (Mississippian) of southeastern Arizona. The Magdalena group is well represented by overlying limestone, the outcrop of which extends far to the north. The granite is exposed in an area of about 1 square mile.

in detail. A very interesting section of the strata[28] is presented in the foothills north of Portal, Ariz., a small settlement and resort 10 miles northwest of Rodeo. (See fig. 43.)

The canyon of Cave Creek just above Portal has been called the Yosemite of Arizona, on account of its great beauty. It is walled with magnificent white cliffs 1,000 to 2,000 feet high, which have been eroded into a great variety of castled and pinnacled forms. The rock is a massive latite, the product of a great volcanic outflow in Tertiary time. The canyon is extremely narrow and tortuous and contains a charming typical mountain stream. There is a good road extending up the canyon and finally crossing the mountain to Sulphur Spring Valley. This mountain region is embraced in one of the divisions of the Coronado National Forest, for the higher portions are covered with pine and other timber. Much of the mountain land is also used for grazing of large numbers of cattle, sheep, and goats.

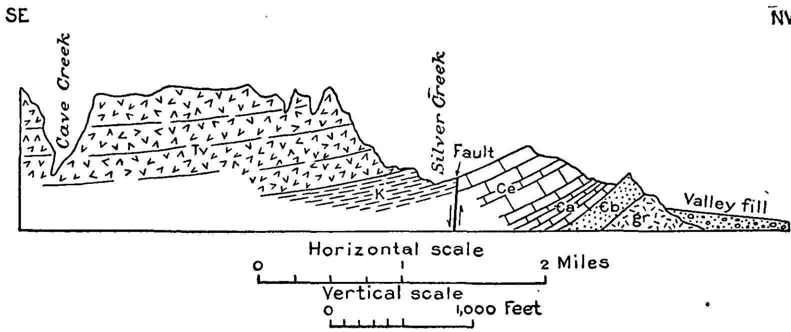

FIGURE 43.—Section of northeastern foothills of Chiricahua Mountains near Portal, Ariz. €b, quartzite with sills of rhyolite (Cambrian); €a, thin-bedded limestone and shale (Abrigo); Ce, limestone (Devonian and Carboniferous); K, sandstone, limestone, and shale (Comanche, Lower Cretaceous); Tv, lava (latite, Tertiary), dipping south at a low angle; gr, granite

Six miles above Portal is Crystal Cave, in limestone (Comanche), which has been only partly explored, and on the west slope are many remarkable pinnacles and other erosion forms developed in the lavas. In various parts of the east front of the mountain there are remains of cliff dwellings, and many of these have also been found in the cliffs of the great succession of volcanic rocks constituting the Peloncillo Mountains east of Rodeo and in the upper part of San Simon Valley. Evidently there was an aboriginal population of considerable size in

[28] The limestones of Carboniferous age include the Escabrosa (lower Mississippian), overlain by about 134 feet of beds in which, near the abandoned mining camp of Paradise, Stoyanow has discovered an interesting assemblage of upper Mississippian fossils; next occur about 3,500 feet of Naco limestone, largely of Pennsylvanian age, but at its top, overlying a 100-foot quartzite member, are 500 feet of limestones in which Stoyanow has collected *Productus ivesi*, *P. occidentalis*, *Meekella pyramidalis*, *Squamularia guadalupensis*, and *Aviculopecten coloradoensis*, a typical Kaibab fauna of Permian age.

this region; and it was also a great resort for the Indians of later times, who found water and good hiding places in the numerous canyons.

In the San Simon Valley at Rodeo and for some distance above and below considerable water is available in the sand and gravel of the valley fill, mostly at depths of 300 to 400 feet. It has been extensively utilized by wells and the water applied to irrigation with excellent results. According to Schwennesen most of the wells penetrate two water-bearing beds, and some of them more. In the central part of the valley, in the vicinity of Rodeo, the first water-bearing beds are from 70 to 80 feet deep, the second from 90 to 100 feet, and the third at about 150 feet. Near Apache the depths are slightly greater. In the San Simon Cienega, 15 miles north of Rodeo, the water comes to the surface in a small area. A well pumped at Rodeo station yields about 200 gallons a minute, and at that rate the water level is lowered 22 feet. The total solids in the well water of this region are only 160 to 364 parts per million, and the principal salt is sodium carbonate.

Two miles southwest of Rodeo the State of Arizona (see p. 147) is entered. The course of the railroad is S. 30° W. through Mora and Apache sidings and nearly to Chiricahua siding, ascending the wide grassy flat-bottomed valley of San Simon Creek. It skirts the bold east front of the Chiricahua Mountains, broken by deep canyons up which are vistas of the high central range with its forest covering. From a point near Mora siding there is an especially fine view of this kind up Horseshoe Canyon. East of the railroad are the steep slopes of the Peloncillo Mountains, consisting of volcanic rocks similar to those on the opposite side of the valley. They lie nearly horizontal, although northeast of Rodeo the succession is tilted to the southeast. Beyond Apache a prominent butte (Squaw Mountain) west of the railroad shows a block of part of the volcanic succession dipping east and probably separated by faulting along its west side. Near by are the remains of a very old Indian settlement of considerable extent. Not far beyond Apache siding the headwaters of the San Simon Valley are crossed, and here begins a flow of black lava (basalt) which occupies a wide area in the valley and extends south to the international boundary.[29] The lava is very fresh and evidently the product of an eruption in Recent geologic time from vents now marked by cinder cones, several of which are visible not far east and southeast of Bernardino siding. The relations of the scoria, bombs, and lapillae in

[29] The lava is black and cellular, and although the sheet is not very thick it presents a surface of extreme irregularity, closely resembling some of the recent flows in other parts of the world. Apparently most of the lava welled out of cracks and spread over the bottom of the valley. As its area widened the surface congealed and the hot lava broke out from underneath, causing tunnels and irregular caved-in areas. That the molten lava was filled with steam is shown by the scoriaceous or honeycombed character of the rock.

one of these cones are well exposed by a quarry and cut a few miles beyond Chiricahua siding. Between two cones 5 miles southeast of Chiricahua siding is a very remarkable crater closely similar in character to the Kilbourne Hole and Hunts Hole, southwest of Lanark. (See p. 134.) Its rim is dimly visible from the railroad. It is a huge oblong hole a mile long and about 200 feet deep. The bottom, now a smooth surface of alluvium, is encircled by a wall of lava of the flow that constitutes the surface of the surrounding country and was probably derived from craters marked by cones to the north and south. Upon this wall is an encircling rim, in places 150 feet high, of fragmentary material, lava, cross-bedded sand, or soft sandstone and many fragments of limestone containing Comanche fossils from strata that underlie the valley and crop out in it not many miles southeast of the crater. (See fig. 44.) This feature is believed to have been caused by a volcanic explosion after the lava flow.

Chiricahua.

Elevation 4,671 feet.
New Orleans 1,374 miles.

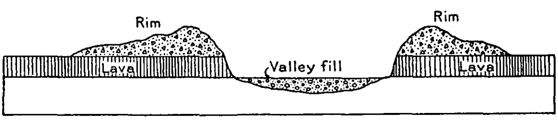

FIGURE 44.—Section across explosion crater 5 miles southeast of Chiricahua siding, Cochise County, Ariz.

This region is called the San Bernardino Valley from an early settlement at the San Bernardino ranch (now the Slaughter ranch), on a Spanish land grant that straddled the present international boundary. The ranch house is about 10 miles southeast of the railroad. A main road to the west, laid out by Lieutenant Colonel Cooke and the Mormon Battalion, a division of General Kearny's Army of the West, went through this place in 1846 and, passing near Douglas, followed down the San

Many of the details of flow are clearly shown by the surfaces, which in some places are ropy, as the lava puckered in congealing, and in others are glassy and smooth like slag from a blast furnace. Many of the tunnels are extensive, and there are also innumerable huge bubbles or blisters more or less cracked by deep fissures due to the contraction caused by cooling. Some flows also have deep crevices due to great emissions or explosions of steam. The margin of the flow presents an irregular edge of low cliffs, such as is shown in Plate 19, *A*, consisting largely of great masses of broken fragments, formed as the congealing lava was pushed along by the advance of the flow. In places a cinder cone was built up at the end of the eruption, undoubtedly marking the location of an orifice. In its last stages the action was mainly a violent escape of steam, which blew out a large amount of cindery or pumiceous material, together with a few hardened masses of lava. This was all thrown to a considerable height in the air and then fell on all sides, quickly building a cone. The recent date of these eruptions is indicated by the fact that the piles of loose material have not been affected by the powerful erosional processes of the region, and there is no perceptible oxidation of the rocks or cinders; the lava still shows the jagged edges due to accidents of flow, and there are many minute stalactites of lava hanging in the roofs of the tunnels. Also, the lava and cinders lie on sand deposits that are of Recent age.

Pedro River to Benson. This road became part of the great emigrant trail of the West, and its existence and relations to a possible railroad route had much to do with the Gadsden Purchase.

In prehistoric times the part of San Bernardino Valley near the springs was occupied by Indians who lived in settlements of considerable size. According to Sauer and Brand, there are many remnants of foundations and "cimientos," or cobblestone walls, and abundant fragments of pottery, implements, ornaments, and a few corn cobs; potteries of various types indicate long occupation and commerce far to the north, south, and east. Probably mesquite beans were the most important food element to these people, but they raised crops on some of the more favorable soils.

Beyond Perilla siding the railroad skirts a lava-covered mesa and, leaving the broad San Bernardino Valley by a huge horseshoe bend, ascends the rocky valley of Silver Creek to a divide at Cazador siding. (See sheet 21.) Near Silver Creek siding sand and conglomerate are exposed under the lava sheet, and volcanic rocks of Tertiary age appear. These rocks present striking exposures in the ridges about South College Peak, where there is a cap of massive latite with strongly marked columnar structure on a large scale. A feeder dike trending east from the foot of the ridge is noticeable 1½ miles south of Silver Creek siding. Near Cazador siding Castle Dome, a huge plug of latite, is visible 5 miles to the north. From this point the course of the railroad is mostly south and southwest over Tertiary volcanic rocks.

Lee.
Elevation 4,411 feet.
New Orleans 1,396 miles.

At Lee siding the railroad passes between two knolls of limestone of Comanche age, which underlies or is faulted against the volcanic rocks, and enters the southern portion of Sulphur Spring Valley. In this vicinity this valley is drained by Whitewater Creek, flowing southeast into Mexico, where it finally empties into the Rio Bavispé, a branch of the Yaqui River, which empties into the Gulf of California near Guaymas.

Douglas.
Elevation 3,980 feet.
Population 9,828.
New Orleans 1,405 miles.

On approaching Douglas the first visible objects are the high stacks of the two large smelters, the Copper Queen and the Calumet & Arizona, on the western edge of the city, where copper ores from Bisbee and other places are treated. Douglas lies near the middle of the wide plain of the southern extension of Sulphur Spring Valley. The valley plain here is about 20 miles wide and extends northward 60 miles to and beyond the main line of the Southern Pacific Railroad in the Willcox region. (See p. 156.) It is deeply covered by sand and gravel washed from the adjoining mountain slopes and known to be nearly 1,000 feet thick. The configuration of these intermontane valleys is highly characteristic, the smooth surface sloping gently up to the foot of the mountains, which rise abruptly with steep rocky slopes. To the east the rugged ridges of the Chiricahua Mountains are visible; 25 miles due north are the Swisshelm Mountains, which consist largely of Paleozoic rocks; and to the west are the Mule Mountains, which rise more than 3,000 feet above the valley and in which the great copper mining center of Bisbee is situated. To the south in Mexico are many high mountains and peaks, mostly of volcanic rock. One conspicuous conical peak to the southeast on the international boundary is the place where the notorious outlaw Pancho Villa assembled his forces before attacking Agua Prieta in 1915

Douglas is on highway 80, which continues west through Bisbee and Tombstone. The city extends south to the international boundary and the small town of Agua Prieta, Mexico (population 2,500), with which it shares an international airport. Douglas, which ranks third in population in Arizona, is a port of entry from northern Sonora, Mexico, with extensive imports. Railroads branch here to Nacozari, in Sonora, where there are large copper mines, and northward up Sulphur Spring Valley to the mining towns of Gleeson, Courtland, and Pearce to join the north line of the railroad at Cochise, 59 miles away. The mines about Gleeson and Courtland are on the east slope of the Dragoon Mountains, in the Turquoise district, so called because turquoise was obtained from the quartzite and granite, mainly by the Indians, who greatly value the blue-green mineral as a medicine stone. The mines, which have been worked to moderate extent since 1883, have produced considerable gold, silver, lead, and copper, and the value of the copper output is more than $8,000,000.[30]

Douglas was named for Dr. James Douglas, who had much to do with the development of the copper industry of the Bisbee district, and it had the advantage of being planned as a city with the definite object of being a smelter and trade headquarters. It began in 1900. The water supply is obtained from wells 3 miles distant.

On leaving Douglas the smelters are passed (south of the railroad), with their huge piles of black slag resulting from the copper smelting. According to the United States Bureau of Mines, in 1928 these smelters had a joint output of 271,400,000 pounds of copper, 5,970,118 ounces of silver, 105,641 ounces of gold, and 14,500,000 pounds of lead, the largest copper-smelting output at any one place in the West. About 1,500 men are employed, many of whom live in the suburb of Pirtleville. In a short distance the railroad crosses Whitewater Draw

[30] The rocks exposed in this vicinity comprise the Pinal schist (Archean), Bolsa quartzite and Abrigo limestone (Cambrian), limestone of Carboniferous age, sandstones of Cretaceous age, and porphyries, granite, and rhyolites of post-Carboniferous age. The rocks are flexed and faulted and also displaced by a remarkable overthrust by which schist and Cambrian strata are carried onto Carboniferous limestone. The ores were formed principally by replacement of the limestone. (E. D. Wilson.)

and ascends the west slope of the wide valley. Near Forrest there are buttes of eastward-dipping limestone of Comanche age (Mural limestone), outliers of the large mass of Comanche strata which constitute the east side of the Mule Mountains.[31] In one of these buttes a short distance west of Forrest is the large Paul lime quarry. The railroad passes around the south end of this range, which shows a few rocky ledges, and crosses the Espinal Plain, which is occupied by gravel and sand.

Bisbee Junction.
Elevation 4,676 feet.
New Orleans 1,427 miles.

At Bisbee Junction there is a branch railroad to Bisbee, 8 miles north, which passes the great concentrating plant of the Copper Queen Co. Bisbee,[32] a prosperous city in the Mule Mountains, is built in a most picturesque fashion in the narrow crooked canyon and along the precipitous slopes of Mule Gulch. It began as a lead camp with small production. The rich Copper Queen ore body was discovered in 1878 and for a few years yielded ore averaging 23

[31] In the Mule Mountains the Comanche series comprises the following formations:

	Feet
Cintura formation; red, nodular shales with cross-bedded buff, tawny, and red sandstone; a few layers of impure limestone near base (surface eroded)	1,800
Mural limestone; upper member massive hard gray limestone; lower member thin bedded and sandy	650
Morita formation; buff, tawny, and red sandstone, some hard, alternating with dark-red shale; a few thin layers of impure limestone near top	1,800
Glance conglomerate; bedded conglomerate with rather angular pebbles, chiefly schist, chert, and limestone of local origin (unconformably on older rocks)	50–75

[32] The formations at Bisbee comprise Pinal schist, Bolsa quartzite, Abrigo, Martin, Escabrosa, and Naco limestones, Comanche series, and igneous granites. The Pinal schists, which are believed to have been originally shales and arkosic sandstones, were folded and metamorphosed to their present crystalline condition in pre-Cambrian time. They are cut by granite and quartz porphyry, which were intruded in a molten condition. The basal Paleozoic formation, lying unconformably on the schist, is the Bolsa quartzite. It is from 400 to 500 feet thick and is overlain by about 750 feet of slabby Abrigo limestone, which has many intercalated cherty layers and is in turn overlain by white limestone, in which Stoyanow has recently discovered many trilobites of Upper Cambrian age. The Martin limestone, 300 to 350 feet thick, is of later Devonian age. Ordovician, Silurian, early Devonian, and later Mississippian time are not represented. The early Mississippian is represented by the Escabrosa limestone, 700 feet thick, and the Pennsylvanian and Permian by the Naco limestone, about 3,000 feet thick. These rocks are overlain unconformably by a thick succession of Lower Cretaceous (Comanche) rocks comprising, at the base the Glance conglomerate, 25 to 500 feet; Morita formation of sandstones and shales, 1,800 feet; Mural limestone, massive above and thin-bedded and in part sandy below, 650 feet; and at the top the Cintura formation, shales and sandstones, 1,800 feet or more. There has been general uplift of the strata with considerable faulting at two or more periods, and erosion has bared the various rocks, in places down to the basement of Pinal schist. The Lower Cretaceous beds were deposited on an unevenly eroded surface of the uplifted rocks, and they in turn have been uplifted, faulted, and eroded. Prior to this epoch of disturbance considerable granite and porphyry were intruded and had much to do with the beginning of mineralization, which progressed at later times. (Ransome.)

per cent of copper. When this ore was worked out new bodies of lower-grade ores were found which have continued to produce a large tonnage, and in 1902 other ore bodies were revealed by the Calumet & Arizona mine. The workings are large and of considerable depth, but all lie in an area of less than a quarter of a square mile. (Ransome.) According to the United States Bureau of Mines about 32,250,000 tons of material has been removed from Sacramento Hill, most of it low-grade ore. About 3,000 men are employed. The copper production of the several mines in 1929 was 186,130,352 pounds, which, together with considerable gold, silver, and lead as by-products, had a value of $35,504,798. The most extensive ores are sulphides, oxides,

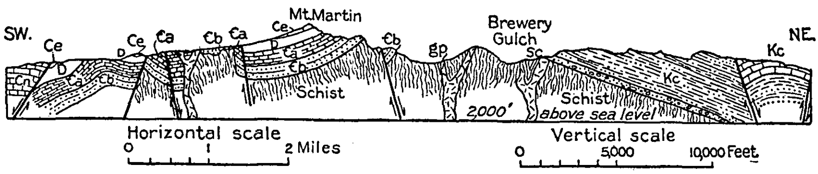

FIGURE 45.—Section across the Bisbee region, Ariz. Kc, Limestones, sandstones, shales, and conglomerate of Lower Cretaceous age (Comanche); Cn, Naco limestone; Ce, Escabrosa limestone; D, Martin limestone (Devonian); Ca, Abrigo limestone; Cb, Bolsa quartzite (Cambrian); sc, schist; gp, granite porphyry. After Ransome

and carbonates. In 1929 their average value in metals was near $12 a ton.

The mean annual precipitation in this region is from 18 to 20 inches.

Naco.

Elevation 4,578 feet.
Population 422.
New Orleans 1,431 miles.

Naco [33] is in the wide Espinal Plain (es-pee-nahl'), which slopes west from the foot of the Mule Mountains into the broad valley of the San Pedro River. This river rises in Mexico, flows north, and finally empties into the Gila River. The San Pedro Valley has had an interesting history, having long been a natural passageway for explorers, travelers, and Indians, including De Niza and Coronado. (See p. 150.)

In 1692, on his first visit, Padre Kino (see pp. 161, 186) named the river Quiburi (kee-boó-ree) from a ranchería of about 500 Indians, near the river not far from Tombstone. It was the home of Coro, the head Pima chief, and it was here that Kino on the expedition of 1697 found the Indians dancing about some Apache scalps they had just obtained. Later American and Mexican settlers in the valley were greatly harassed by hostile Indians, until the final subjugation of the Apaches in 1886. The earliest American settlers were four Mormon families from the colony established near Mesa, Ariz., by

[33] In March, 1929, Naco, Mexico, just across the boundary from Naco, Ariz., was the scene of a severe battle between Mexican troops and revolutionists, in which the latter, by the aid of bombs dropped from airplanes and attacks by tanks, were victorious.

Brigham Young in 1878. These settlers founded St. David. It was down the San Pedro Valley in 1846 that Colonel Cooke laid out the military road to the West that was used extensively by later travelers. His troops were made up largely of Mormons who entered the service in order to reach California, where their term of enlistment would end.

The railroad reaches the bottom of the San Pedro Valley at Hereford and follows it northward to Benson. Near Hereford and for some miles north the prominent Huachuca Mountains (wah-choo'ca) form the west side of the valley, attaining an elevation of over 9,000 feet in Miller Peak and Carr Peak. It is included in a division of the Coronado National Forest. At its north end is Fort Huachuca, a frontier military post reached by a 13-mile branch railroad from Lewis Springs.

Hereford.

Elevation 4,189 feet.
Population 221.
New Orleans 1,443 miles.

The San Pedro Valley is from 15 to 20 miles wide in greater part, and with steep lateral slopes and a declivity of nearly 600 feet in 40 miles it is very different in character from the basinlike Sulphur Spring Valley, which lies a few miles east. This difference is due to the erosion of a vigorous river which trenches deeply into the thick valley fill, especially in the region below Lewis Springs. At Lewis Springs and at intervals northward porphyry is revealed in the valley bottom, which is apparently on the crest of an underground ridge connected with the porphyry area so extensively exposed about Tombstone. This noted mining camp lies 8 miles east of the main railroad and is reached by a branch line from Fairbank, where there is also a branch railroad leading to Patagonia.

Lewis Springs.

Elevation 4,027 feet.
New Orleans 1,453 miles.

Tombstone is on the gentle slopes of the Tombstone Hills, overlooking the San Pedro Valley. The ore deposits [34] were discovered by Ed. Schieffelin almost by accident in 1878, the great strike occurred in 1879, and the town was established in 1881 with the name Tombstone because someone predicted to Schieffelin that his prospecting

[34] According to Ransome the Tombstone mining district presents a local uplift of Paleozoic rocks lying on a basement of pre-Cambrian schist and granite and overlain by sandstone, shale, and limestone of Lower Cretaceous (Comanche) age. There are also larger masses of granitic rocks and porphyry that cut all the strata, causing considerable metamorphism, which apparently had much to do with the deposition of the rich silver ores in the limestone. The basal strata are 440 feet of Bolsa quartzite and 700 feet of Abrigo limestone (both Cambrian). Next above are 340 feet of Martin limestone (Devonian), 500 feet of Escabrosa limestone (Mississippian), and 2,000 to 3,000 feet of Naco limestone (Pennsylvanian and Permian). There is much faulting. The greater part of the silver ore was found in the limestone of the overlying Comanche series, partly as replacement deposits in the limestone and partly in fissures. Some ore occurred in altered porphyry dikes. The largest replacement ore bodies were mostly in the anticlines in the vicinity of dikes or fissures. The manganese ore occurs as a replacement deposit in the Naco limestone.

would yield only a tombstone. The Silver King was a famous producer of rich ore which assayed $2,200 and some of it even $9,000 in silver to the ton. Later several rich mines were combined and operated profitably until flooding of the largest mine threw the company into legal difficulties, during which most people left Tombstone. After years of litigation the principal group of mines was sold at auction for $500,000, and production at Tombstone was resumed in a small measure, for a time. After the silver mines were abandoned it was found that the associated deposits of manganese ore could be marketed, and in 1918 the old Oregon mine was producing about 2,000 tons a month of this ore for use in small proportions in iron making to improve the quality of the pig iron. Tombstone is now a city of 850 inhabitants with hopes that additional ore bodies will be discovered some day and restore the former prosperity. It is the scene of the Wolfville stories of Bret Harte and many other books and stories by various authors and the place where the famous newspaper "The Arizona Kicker" was published; the present newspaper bears the name "Tombstone Epitaph." Its historic "Bird Cage Theater" in boom days housed some great actors.

Charleston.

Elevation 3,971 feet.
Population 25.*
New Orleans 1,457 miles.

Fairbank.

Elevation 3,853 feet.
Population 197.
New Orleans 1,464 miles.

The small village of Charleston, on the banks of the San Pedro River, at one time had a smelter and was noted as a wild frontier town. From Fairbank the railroad ascends the west side of the San Pedro Valley and passes northwestward around the northeast side of the Whetstone Mountains (p. 161). (Turn to sheet 22.) At Mescal it crosses (on a bridge) the old main line of the Southern Pacific, now used for eastbound traffic between Tucson and Mescal, and is joined by the line from El Paso by way of Deming, Lordsburg, and Bowie.

MESCAL TO TUCSON, ARIZ.

Mescal.

Elevation 4,064 feet.
New Orleans 1,461 miles by north line, 1,490 miles by south line.

At Mescal the north line (formerly the main Southern Pacific line from El Paso to Tucson) (pp. 131–162) is crossed by the south line (formerly the El Paso & Southwestern Railroad from El Paso to Tucson), which comes by way of Douglas (pp. 162–178). The two lines are closely parallel from Mescal nearly to Tucson, and practically the same features are to be observed over both lines. The tracks are now so connected by switches at Mescal that all westbound traffic, whether from Benson or Douglas, passes onto the north track; eastbound traffic comes to Mescal on the south track, trains for Douglas diverging just east of the station to the old El Paso & Southwestern tracks. Near Irene siding, 15 miles west of Mescal, the north track with its westbound traffic is bridged across the eastbound track and continues south of it into Tucson.

Desert conditions prevail all the way across southern Arizona, where the annual rainfall in the wide valleys is 10 inches or less. Most of the characteristic plants continue westward, notably the ubiquitous creosote bush, the mesquite, the yucca, the weird-looking ocotillo, and many cacti. On the adjoining mountains the rainfall is greater and there is a consequent difference in vegetation, and the higher summits carry extensive pine forests. The desert plants present many features of interest, especially in the flowering season, when some of them are of great beauty. On the lower rocky slopes grows the biznaga, or "barrel cactus" (*Echinocactus wislizeni*), with its large barrel-shaped body covered with curved thorns and bearing bright-red flowers in early summer. It contains much watery sap, which can be used to quench thirst very satisfactorily in case of necessity and has often been a life saver for man and beast. To obtain water the top is cut off and the liquid pressed out of the interior pulp, as shown in Plate 20, *B*. This pulp is also used in making candy. There are also the smaller *Echinocactus johnsoni* and clusters of the nigger-head cactus, *E. polycephalus*, which bears beautiful deep-red flowers in the early summer. All these cacti are covered with large spines and contain considerable water which is protected from evaporation by the thick skin of the plant. The desert rats, however, gnaw into some of them and clean out their watery pulp, leaving an empty shell. The yellow-looking, very spiny, branching cactus (mostly *Opuntia fulgida*) begins to be conspicuous in the region west of Mescal and is a prominent member of the desert flora all across southwestern Arizona.

Here also begins the sahuaro (*Carnegiea gigantea*), a treelike cactus with round fluted trunk which may reach a height of 50 feet; most of these strange plants bear branches that start high on the trunk and turn upward so as to produce the appearance of a giant candelabrum, as shown in Plate 31, *B*. The sahuaro is covered with thorns and in May bears at the top a cluster of white flowers, which in June develop into fruit that is in great favor with the Indians and birds. The Indians make from the fruit a kind of fig paste, also molasses, and an intoxicating drink. Garcés found the Indians greatly addicted to this drink at the time of his travels in 1775. Many birds make their nests in holes in the trunk, which they excavate in the soft pulpy material, but in a short time these cavities are sheathed with plant tissue which prevents sap leakage. It is stated by Spalding that most of these holes are made by the Gila woodpeckers (*Melanerpes uropygialis*), but they are utilized by other species, such as the sparrow hawk, screech owl, purple marten, and flycatcher. To this giant cactus the elf owl (*Micrathene whitneyi*) resorts when breeding; it is the smallest of owls, only a little larger than the humming bird. The gilded flicker is also fond of the sahuaro and rarely found elsewhere.

A woodpecker with a red head (male) and a black and white ladder-striped back so greatly prefers the branching cacti for its nest that it is called the cactus woodpecker (*Dryobates scalaris cactophilus*).

The sahuaro is a huge reservoir of water, made up of rods about an inch in diameter connected by plant tissue so that it has considerable strength to withstand the wind and also great capacity for rapid expansion when rain brings a supply of water. When dead the sahuaro loses its pulp, leaving a spectral skeleton of a bunch of tough wooden rods that burn with a bright flame; they are much used by the Indians for sheathing huts and making inclosures. The sahuaro prefers southward-facing slopes of rocky character where its roots can penetrate the soil between the rock fragments; basalt and tuff are favorable, but caliche appears not to be.

Members of the cactus family have remarkable ability to store water, because the roots extend widely, for the most part only a few inches below the surface, so as to absorb a quantity of water from the soil very quickly after a rain. It has been found by investigations by MacDougal, Spalding, and others at the Desert Botanical Laboratory at Tucson that once stored in the plant tissues, this water is retained with great tenacity as a provision for long, dry intervals. Water absorbed by plants is expended continuously in the process of living, mostly by evaporation through their green surface. While most of the cacti have leaves, as a rule these are minute or even microscopic (the conspicuous parts are botanically stems, not leaves), and the structure of their cells is such as to hinder transpiration and conserve the water stored. The slowness of chemical reactions in these and most other desert plants aid in the conservation of moisture. In the walls of the cells of the cacti are thin sievelike places which permit the easy passage of water from one cell to another throughout the interior. A barrel cactus was found to contain 96 per cent of water. A large sahuaro contains many gallons of water, sufficient to maintain it for a year or more. The water in some cacti is palatable, but that in others is very bitter, and it is interesting to note that those of the latter class are less protected by spines than those whose juice is acceptable. The spines of the cactus are straight or curved, hairy or feathery, and grouped in starry clusters or in rows. They have been used for fishhooks, needles, combs, and in various other ways by the primitive tribes. The flowers of the cactus vary in form, and most of them are beautiful in brilliant tints of purple, yellow, orange, and rose. (See pl. 31, *A*.) Some open by day; others, such as the night-blooming cereus, by night. Many of the species bear edible fruits, several of them delicious, and some of them yield seeds used by the Indians for food. In Arizona the cacti and some other desert plants are legally protected from removal, with a fine of $50 to $300 for each offense.

The maguey (mah-gay′) (*Agave parryi*) and sotol (*Dasylirion wheeleri*) are scattered on many slopes, the former greatly preferring the rocky limestone areas. (See pl. 22, *A*.) Sometimes the maguey is called the "century plant," with the idea that it blossoms once in a hundred years, but the period is generally only six or seven years, and after the fruit is developed the plant dies. It is a useful plant to the Indians, who make tough fiber from its leaves. The bulbous base of its young staff when baked is like squash, and it also furnishes juice which when fermented becomes pulque (pool′kay) and when distilled yields the strong brandies "mescal" and "tequila" (tay-kee′la). Many piles of stones in the Southwest mark the sites of "mescal pits," where the plant was roasted by the Indians.

The broad stiff-leaved yuccas (*Yucca macrocarpa* and *Y. baccata*), called "dagger" or Spanish bayonet, bear large white flowers in bunches on a tall stalk, which develop into an edible fruit, "datil," somewhat like the pawpaw, that is utilized by the Indians. Their fiber is also used extensively for basket weaving. The abundant narrow-leaved yucca with its stalk of beautiful white blossoms (palmilla of the Mexicans) is called soap weed because its roots (called amole) make a soapy lather when pounded in water. Beargrass (*Nolina*) is a different plant but also contains an excellent fiber.

The more noticeable desert trees which grow in nearly all parts of western Arizona are the mesquite (*Prosopis glandulosa*), which often attains a height of 30 feet along the valleys, the palofierro, or ironwood (*Olnega tesota*), and the paloverde (*Cercidium* and *Parkinsonia*), many of which grow to be more than 300 years old. There are a few chiriones, or soapberry trees (*Sapindus marginatus*), and desert willows (*Chilopsis linearis*) in the arroyos. The "Crucifixion" bush, consisting entirely of thorns, and the indigo thorn (*Parosela spinosa*) are interesting bushes of widespread occurrence. The very thorny catclaw, "uñas del gato" (*Acacia greggii*), merits its name, and there is another *Acacia* (*constrieta*) called "tisito," which bears globular yellow flowers of remarkable fragrance. On the higher lands are many junipers (sabinas), the piñon (*Pinus edulis*) with its delicious nuts, and many oaks.

Three miles west of Mescal, in the headwaters of Pantano Wash, there are outcrops and cuts in sandstone of Lower Cretaceous (Comanche) age that underlies the wide, low divide of the Mescal region, and farther west, notably near Pantano, there are scattered exposures of tilted conglomerates, sandstones with interbedded lavas, and Gila conglomerate (Pliocene and Pleistocene). A massive volcanic rock is exposed in the stream gorge about 80 feet deep just east of

Irene, where the two tracks cross and where also the highway crosses the stream and railroad. Farther west, downstream, are exposures of agglomerate, a breccia or conglomerate of volcanic origin.

Pantano.

Elevation 3,547 feet.
Population 30.*
New Orleans 1,472 miles.

As the train approaches Marsh and Pantano sidings and from these places to Vail, there are seen to the south the Empire Mountains,[35] culminating in Mount Fagan (elevation 6,175 feet). In these mountains there are many small mining prospects, mostly of silver ores; mines about Helvetia, on the western slope, have produced ore in moderate amount. This range extends south to the Santa Rita Mountains, in which there are several small mines, notably near Greaterville and Old Baldy. Some of the geologic relations are shown in Figure 46.

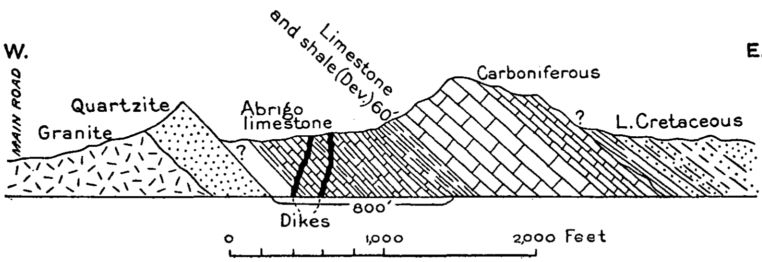

FIGURE 46.—Section 1 mile north of Helvetia mining camp, Ariz.

Vail.

Elevation, 3,233 feet.
New Orleans, 1,480 miles.

From points near Vail it may be seen that the Rincon Mountains merge into the Tanque Verde Mountains (tahn′kay vare′day), which in turn merge into the Santa Catalina Mountains, to the northwest. The ranges are separated by saddles, and each one has a prominent projection to the west. The prevailing rock in these ranges is a hard massive schist, but the Santa Catalina Mountains include toward the north a large mass of granite. On the west end of the Rincon Mountains Carboniferous limestone and other strata form foothill ridges which

[35] In the various ridges of the Empire Mountains are exposed Bolsa quartzite, Abrigo limestone, Martin and overlying Carboniferous limestones, sandstones and shales of Lower Cretaceous age, granites, and small areas of volcanic materials. The principal structural feature is an overthrust of a block of Carboniferous and Devonian limestone on pre-Cambrian granite that constitutes part of the summit and the northwestern slopes. To the southwest these limestones are overthrust onto Lower Cretaceous strata. Bolsa quartzite (Cambrian) is exposed in Davidson Canyon. The outer slopes of the mountains consist of sandstone, shale, and conglomerate of Lower Cretaceous age, which toward the east lie unconformably on the Paleozoic limestones, in places with a basal conglomerate consisting of pebbles and cobbles of various colored limestone, quartz, and other materials. This unconformity indicates a time break of many millions of years represented elsewhere by late Paleozoic, Mesozoic, and Jurassic strata.

approach the railroad between Pantano and Vail.[36] Three miles east of Vail, a cavern known as Colossal Cave extends far underground with many interesting galleries, some of them with stalactites and stalagmites. Formerly it contained guano which was excavated for shipment to Los Angeles for use as fertilizer. The interesting relations of the rocks in this vicinity are shown in Figure 47.

Near Vail and westward the wide, level desert plain extends east and south to the Empire and Santa Rita Mountains, north to the Rincon and Tanque Verde Mountains, northwest to the Santa Catalina Mountains, and west to the ragged peaks of the Tucson Mountains. It slopes west into the wide arroyo of the Santa Cruz River.

The prominent Santa Catalina Mountains, just north of Tucson, present a formidable array of rugged cliffs, separated by high-walled canyons heading deep in the range. These mountains consist of a large central mass of very coarse pegmatite and granite, which weathers to picturesque pinnacles and balanced rocks; they are the latest of a series of granitic intrusions, one of which, known as the Oracle granite, is exposed in a large area around Oracle. On the southwestern slopes of the mountains the rocks are dominantly gneisses, which are well layered and which form the rugged crests and slopes of the numerous canyons. On the northeastern slope there are extensive outcrops of the Apache group, comprising the Scanlan conglomerate, the Pioneer shale, the Barnes conglomerate, the Dripping Spring quartzite, and the Mescal limestone, which is here a shale. These have been greatly metamorphosed by the later granites of post-Paleozoic age, which have also changed the overlying Cambrian, Devonian, and Carboniferous strata. (B. N. Moore, personal communication.)

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[36] The larger ridges consist of massive gray-blue limestone, Martin (Devonian) and Escabrosa (Mississippian), but in places this limestone is replaced by silica in large bodies which might easily be mistaken for quartzite. Under the Martin limestone is the Abrigo limestone, mostly very impure and sandy, carrying fragments of trilobites, lingulas, and other fossils characteristic of Upper Cambrian time. This is underlain by hard sandstone, which has been found by Stoyanow to contain Middle Cambrian fossils. Next below is hard reddish bedded quartzite with intrusive sills of diabase, which resembles the Dripping Spring quartzite of the Apache group. Under this is red shale like the Pioneer shale and at the base a conglomerate resembling the Scanlan conglomerate of the Apache group, lying on granite. The diabase closely resembles in character and relations the diabase in the Apache group farther north in Arizona. The beds are broken by many faults, and the higher limestones are pushed northeastward over the gneiss of the Rincon Mountains along the plane of a great overthrust. The movement on this thrust is measurable in miles. The thrust is well exposed on the northeast end of the larger limestone ridge, as shown in section A, Figure 47. Here the plane of displacement slopes to the southwest at a low angle. In this portion of the area a 38-foot bed of quartzite of unknown age overlies the Abrigo and apparently separates it from the Martin limestone, as in the Bisbee and Johnson areas.

It is believed that the steep southern and western sides of the Santa Catalina Mountains are determined by a great fault, for the

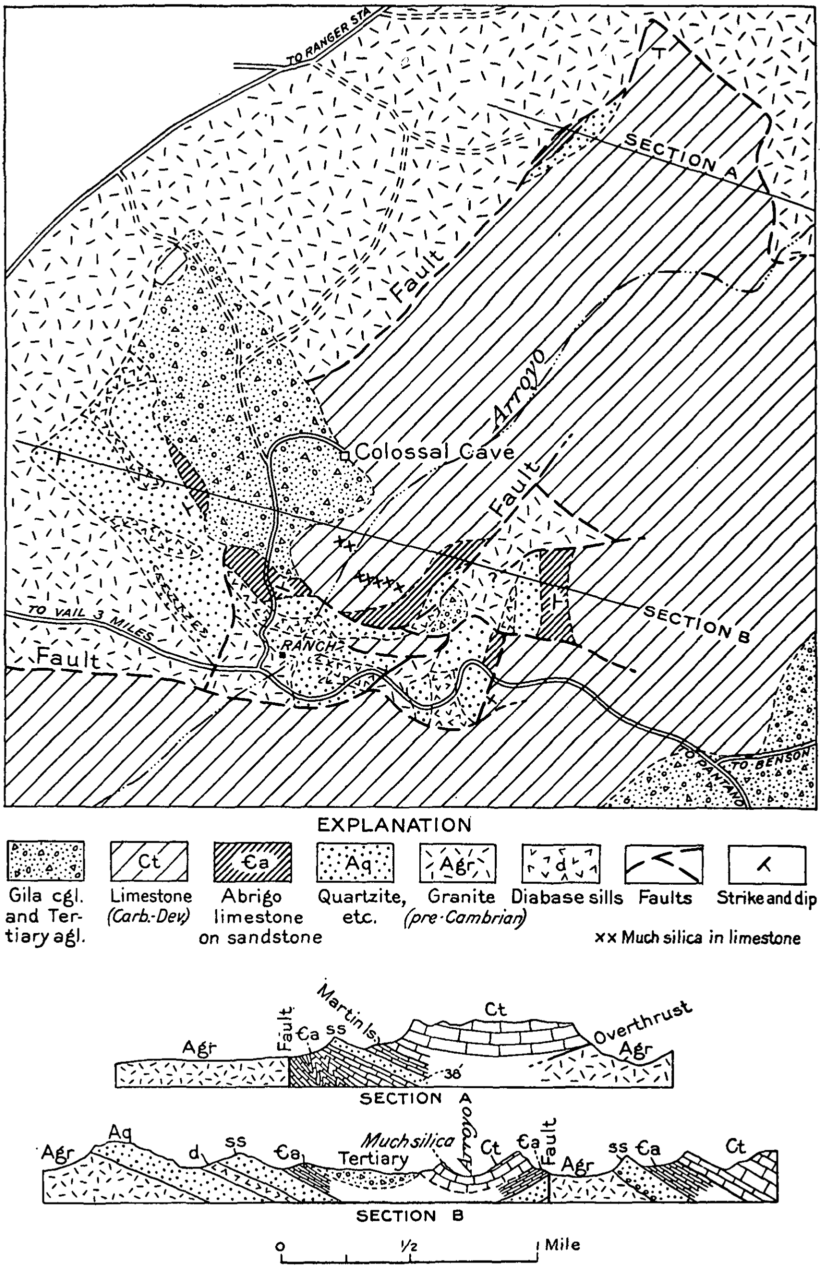
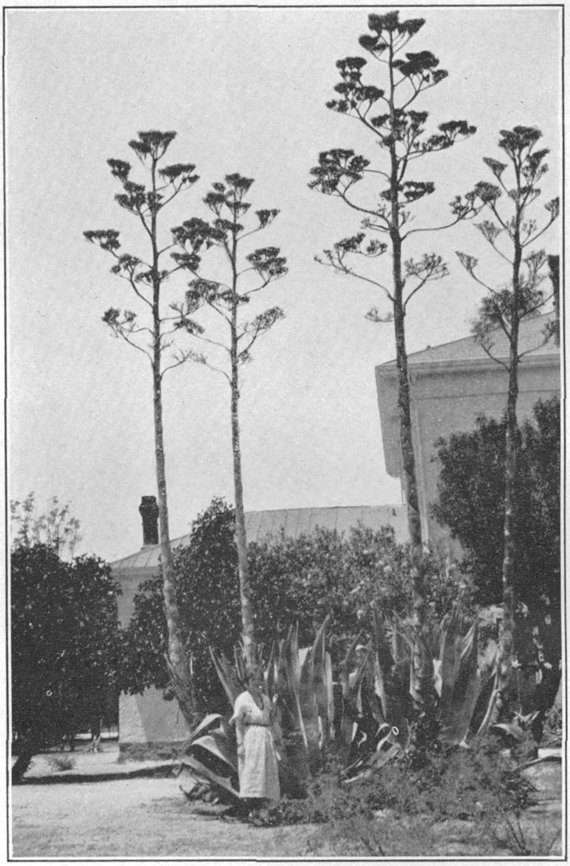


FIGURE 47.—Geologic map and cross sections in the vicinity of Colossal Cave, 3 miles east of Vail, Ariz.

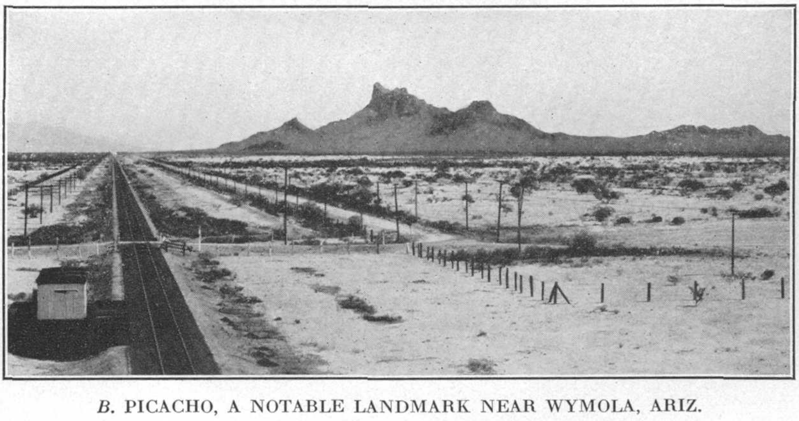
strongly marked bedded structure of the schists dipping to the west is abruptly cut off on those sides. The upper part of the range

THE OLD MISSION OF SAN XAVIER DE BAC
Ten miles south of Tucson, Ariz.



A. MAGUEY (AGAVE PARRYI)

Abundant on many limestone hills in the Southwest. About 7 years is required for development, after which it dies. Allied species are the source of the Mexican drinks mescal and pulque.



B. PICACHO, A NOTABLE LANDMARK NEAR WYMOLA, ARIZ.

A mass of volcanic rock of Tertiary age. Looking southeast.

appears to be the remains of an old erosion surface, now deeply dissected, on which the Mount Lemmon highland rises as a rounded swell, probably a residual mound. The northwest corner shows evidence of later upbending of 1,000 feet or more. (W. M. Davis.) Rising to the south foot of the mountains is a steep slope of sand and gravel underlain by sandstones and conglomerates of supposed late Tertiary age revealed in the deeper canyons. The beds dip steeply away from the mountain front and in places are considerably faulted. The high Tanque Verde and Rincon Mountains, east of Tucson, also consist of gneiss. All these mountains are included in a national forest, for their higher parts sustain a growth of valuable timber; many live oaks and junipers occur from 4,500 to 6,000 feet, the yellow pine thrives between 6,000 and 8,000 feet, and there are small areas of fir and spruce above 8,000 feet. On the lower slopes sahuaros are numerous, notably on the west slope of the Tanque Verde Mountains, 15 miles east of Tucson, where the State University has reserved an area in which these interesting plants are especially abundant and large.

TUCSON TO PICACHO, ARIZ.

Tucson.
Elevation 2,389 feet.
Population 32,506.
New Orleans 1,499 miles.

Tucson, the second city in size in Arizona, is the oldest settlement in the State and can boast of a colorful history. For many years it was a small, rough frontier town, preponderantly Mexican in population and appearance. Now it is a well-ordered city containing the State University, with an enrollment of more than 3,000 students, many high-class hotels, clubs, and a large residential district of particular beauty and charm. These features, in addition to the mild, healthful climate, attract many new residents, as well as tourists.

The State University, which is now accredited by the American Association of Universities, was built on ground donated by three leading gamblers of the city, and the first building was constructed before there was a high school in the Territory; during its first years students had to be taught the prerequisites to its freshman course. The university includes the Arizona Bureau of Mines, which is making investigations of the mineral resources of the State, and the Stewart Observatory for astronomical research. An important investigation conducted by Prof. A. E. Douglas has established a chronology of tree rings, which gives a key to the age of logs used in aboriginal houses and even to some that occur in petrified condition. There are at Tucson also the Desert Laboratory of the Carnegie Institution and a seismologic observatory of the United States Coast and Geodetic Survey.

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According to long observations by the United States Weather Bureau the average annual precipitation at Tucson is 11.8 inches, usually with the maximum rainfall in July. The precipitation shows wide variation, however, sometimes falling considerably below 10 inches (5.26 inches in 1885) and occasionally exceeding 15 inches (24 inches in 1905). The mean annual temperature is 67.3, and the humidity is generally considerably under 50 per cent. The daily range in temperature ordinarily varies from 32° to 57°. The average number of sunshiny days in the year is 309. Snow is rare in the valley but often falls heavily on the surrounding high mountains.

Tucson is built on the nearly level desert on the east bank of the Santa Cruz River, a wide watercourse which is dry most of the time. In every direction are fine views of the splendid mountains that encompass the far-reaching desert flat. To the north is the high Santa Catalina Range, which rises more than a mile above the slopes at its base; its highest summit, Mount Lemmon (elevation 9,150 feet), is in plain sight. This range is continued far to the east in the Tanque Verde and Rincon Mountains. To the south are the Santa Rita Mountains and the Sierrita Range, separated by the valley of the Santa Cruz River, and to the west and northwest are the pinnacled Tucson Mountains, not high but very rugged. Beyond the Sierrita Mountains is a distant view of the prominent Baboquivari Peak (bah-bo-kee-vah′ree).

There was considerable mining in the general region about Tucson by Spaniards, Mexicans, and Americans down to 1861, when all industry ceased. It was revived in 1878 with the discovery of rich ores at Tombstone. Several productive mines are now in operation in the Empire, Santa Rita, and Sierrita Mountains. In the Twin Buttes, on the east side of the Sierrita Mountains, there are mines producing ores of silver, copper, and lead.

The Santa Cruz River rises in Mexico south of Nogales, and on the rare occasions when it carries a large flood it empties into the Gila River southwest of Phoenix; its total length is thus about 200 miles. With the advent of the missionary-explorers, in the early days, its valley became an important artery of travel from the western part of Mexico to Arizona and the north and west. The first of these explorers of whom there is authentic record was the heroic German Jesuit Eusebio Francisco Kino, who spent 20 years in constant journeying, often entirely alone, throughout the Indian region as far west as the Colorado River. He left Mexico City in 1687 and, after founding several missions in northern Mexico, reached the Indian rancherías of Guevavi and Bac, on the Santa Cruz River, in 1691. In the next few years he reached the coast of the Gulf of California and also discovered Casa Grande, on the Gila River. He visited Mexico City in 1695. In 1696 he reached Quiburi (kee-boo′ree), the Indian settlement on the San Pedro River. He visited this place again in 1697 and followed the San Pedro and the Gila to and beyond Casa Grande. He returned by Bac,[37] 9 miles south of Tucson, where he laid the foundation of the church of San Xavier in 1700. At that time Bac had a population of 830, with 176 houses, extensive wheat fields, and much well-tended livestock; it was the largest ranchería in the Pima country.

In 1700 also Kino descended the Gila River to its mouth, and in 1701 he returned to the vicinity of Yuma and crossed the Colorado River on a raft. The observations made on these explorations convinced him that California was not an island. In 1702 he made another journey to the mouth of the Colorado and other places. He continued his travels for a few years more, taking his last view of the Gulf of California in 1706. He died at Misión Dolores in Mexico in 1710 or 1711, at the age of about 70 years. In some of these great journeys he was alone; in others he was accompanied by Father Juan María Salvatierra and Capt. Juan Mateo Mange. At that time there were no other Spaniards in the Southwest, so that these journeys were lonesome and hazardous, but Kino found the Indians perfectly friendly and eager to learn, and they gave him guidance and supplies. His persistence and endurance were phenomenal.

A mission was conducted at Bac by the Jesuits from 1701 to 1767, when that order was expelled by the Spanish Government and the Franciscans placed in charge of all missions. One of the Franciscan missionaries located in San Xavier was Padre Francisco Garcés, the great explorer whose journeys down the Santa Cruz Valley and over a wide region as far as Utah and California during a period of 13 years constitute one of the most brilliant chapters of American history. Born in Spain in 1738, he was 30 when he entered upon his heroic career as missionary to the Indians of Pimería Alta. His first "entrada," in 1768,[38] was from Bac to the Gila River, and later he proceeded down that stream to its mouth and crossed the Colorado, finally reaching the Mission San Gabriel in California. In 1775 he accompanied Captain Juan Bautista de Anza's expedition to found San Francisco as far as the Colorado River and then made a great trip alone, circling to the north and returning to Bac by a route that gave him a glimpse of the Grand Canyon, being thus the first white man to approach that great spectacle from the west. He gave it the name Puerto de Bucareli. In 1779 he established his ill-fated colony in the Yuma region and was massacred with it on July 19, 1781. He is now buried in San Pedro de Tubutama, in Sonora. A coworker, Padre Pedro Font, has written of him: "He is so fit to get along with the Indians and go about among them that he seems just like an

[37] Bac, a Pima word frequently encountered, means house, adobe house, or a ruined house.

[38] Garcés' travels have been described in detail by Coues (Diary and Itinerary of Francisco Garcés, 1775–1776, 2 vols., Harper, 1900).

Indian himself. In fine, God has created him, I am sure, totally on purpose to hunt up these unhappy, ignorant, and boorish people."

The present beautiful and interesting church of San Xavier at Bac, shown in Plate 21, was rebuilt very near the site of the first church, which was destroyed in the Indian outbreak of 1751. It was begun probably in 1783 and finished in 1797 (the date carved on the sanctuary door), during the period of comparative peace and prosperity that extended from 1786 to the end of the Spanish rule in 1822. The church is still in use, together with a school for the Indian children of the neighborhood.

In the immediate vicinity of the present Tucson there were several early Indian villages which doubtless were passed by Father Kino in his journey to Casa Grande in November, 1694. The first Spanish settlement in the immediate neighborhood appears to have been San Agustín de Tucson, located on a low ridge 3 miles northwest of the present city hall, some time prior to 1763. It led a precarious and intermittent existence owing to Apache depredations, as did also the small Indian village of "San Cosme de Tucson," [39] which sprawled at the foot of Pinnacle Peak, now familiarly known as "A" Mountain, from the great white initial annually inscribed upon it by university students. Here under the guidance of Padre Garcés an hacienda and small settlement were established in 1776; this was known as El Rancho de Tucson and later as El Rancho del Padre. Half a mile northwest a mission was built under the name San Jose de Tucson. About this time the Spanish garrison was transferred from Tubac, 44 miles away, to San Agustín de Tucson and later to the present site of Tucson. Around the presidio at Tucson was built an adobe wall 12 feet high with low towers and parapets, one corner of which is marked by a bronze tablet. This diminutive walled city became the metropolis of the Southwest and for a long time marked our extreme western frontier. The valley was richly productive, mining was successful, and the hills were covered with herds of wild cattle. On the withdrawal of soldiers and missionaries from southern Arizona before and after the war of Mexican independence, the Apaches resumed their depredations, killing many persons and destroying 100 houses and several settlements. At this time from 3,000 to 4,000 settlers left the country, only a few remaining at Tucson. It is stated by Lockwood that in 1848 the population of Tucson was 760 and Tubac 249 and that Tubac was abandoned at the end of that year.

Even under American rule it was not until after the Civil War that Apache and other warring Indians were finally conquered and banished to reservations. Fort Lowell, the old United States Army post, of which the ruins still stand 7 miles northeast of Tucson, was estab-

[39] The name Tucson means "the foot of a black hill," from the Papago Indian words tjuik, meaning black, and son, meaning foot of, or "the place of dark springs," from the Sobaipuri name "Stookzonac." (Lockwood.)

lished in 1862, abandoned in 1864, reoccupied in 1865, and moved in 1873. It was named for Gen. C. R. Lowell, of the United States Cavalry. After the Gadsden Purchase Americans began to arrive, not a few being encouraged to journey thither by sheriffs and vigilance committees of neighboring States. With these came sturdier citizens with true pioneer spirit, but no white woman resided permanently in Tucson until 1870.

On the outbreak of the Civil War in 1861 Tucson was seized by Confederate troops from Texas, who in turn withdrew on the approach of the Union volunteers from California (the "California Column") under Colonel Tarleton. (See p. 154.)

The stage from San Antonio to San Diego began making two trips a month late in 1857. For a while it passed through Tucson, but later it followed a more northern route in the Gila Valley. Tucson was on the oldest highway from the Rio Grande to Yuma and the Pacific coast, and traders and Government wagons with supplies for the various army posts in the Apache country were constantly on the move. The railroad arrived in 1880, and this fact was heralded to the world by telegrams from the proud citizens to the President at Washington and the Pope at Rome.

Near Tucson there is a small settlement of Papago (pah′-pa-go) Indians (527 in 1932) at the mission of San Xavier at Bac, and there are also two small settlements of Yaqui Indians from Mexico on the western and southern margins of the city.

The Indians now known as Papagos live mostly in a large reservation in the desert southwest of Tucson (4,914); on the Gila Bend Reservation, west of Phoenix (224); and in the Chiu-Chiuschu Reservation, south of Casa Grande (349). The Indians of this region claim descent from the builders of Casa Grande (see p. 197), and they are a branch of the Piman family. The "Pimas" lived in the Gila and Salt River Valleys, the Papagos in the Santa Cruz Valley and west into Sonora, Mexico. Another Piman tribe, the Sobaipuri, now extinct, occupied the San Pedro and Santa Cruz Valleys during Kino's time, when it was estimated that the total Pima population was about 12,000. The Papagos ("bean people") are a large-framed, well-formed people of dark skin and rather bold, heavy features. The women are of more delicate mold than the men, and some of them are decidedly handsome. The bravery of the Papagos has been proved in many conflicts with the Apache and other predatory Indians, and they have been uniformly friendly to the whites. Many of them are industrious and good workmen. Their life is closely adjusted to the arid region in which they live, especially in the matter of water supply for themselves, the use of flood waters for irrigation, and the utilization of the scanty natural food resources. They often have had to move to places favorable to their interests, and at times starvation has taken many lives. Mesquite beans and the fruit of the sahuaro, pitahaya, and agave, besides acorns and camote, an edible root, are important food resources, especially in poor seasons; formerly there was considerable game. One of their principal trading commodities is salt, which they gather from lagoons on the shore of the Gulf of California. The Papagos are divided into clans, two of which are included in the "red velvet ants," who are regarded as the original owners of the country, and the others in the "white velvet ants," who have come later. Descent in these clans is by the male line, which is contrary to the custom of the Pueblo Indians. The Papagos of San Xavier apparently absorbed the Sobaipuris, the last of whom, Encarnación Mamaxe, died at San Xavier Mission early in 1932, at the age of 106 years. The Papagos regarded the sun as the "Father," and their principal deities were the "Elder Brother" and the "Earth Magician," but most of them are now Catholics.

The Desert Laboratory occupies 860 acres on the Tumamoc Hills in the western part of Tucson. It was established in 1903 with the belief that this location offered the greatest opportunities for studying desert vegetation and the problems of its growth, its enemies, and soil relations. In 1905 it was made the headquarters of the department of botanical research of the Carnegie Institution of Washington. It has obtained a large amount of most valuable information regarding plant growth, soils, and water conditions in the desert. The State Agricultural Experiment Station at the university has branches in various parts of Arizona, studying many problems of crop, fruit, cotton, and nut production.

Tucson obtains its water supply from wells that draw from the underflow of the Santa Cruz Valley south of the city. In the Rillito Valley (ree-yee'toe), just north of Tucson, underground water is pumped for irrigation. When old Fort Lowell was located in this valley, at the mouth of Pantano Wash, the cavalry horses were fed with hay cut from the flood plain, which is now dry and deeply trenched.

From Tucson a branch line of the Southern Pacific system ascends the Santa Cruz Valley to Nogales, on the international boundary, and thence goes to Guaymas (10 hours), Guadalajara (48 hours), and Mexico City (65 hours). At 44 miles south of Tucson it passes the ruins of the old Spanish presidio of Tubac, which dates prior to 1752 and was erected to protect the neighboring missions. At this place in 1858 to 1860 a small group of Americans and Mexicans partly restored the ruins and published the "Weekly Arizonian," the first newspaper in the Territory. A short distance beyond Tubac is the old Tumacacori Mission (too-ma-ca'co-ree), established by Father Kino in 1702, now a most interesting national monument under Government protection.

Westward from Tucson the railroad crosses the southwestern portion of Arizona, a region presenting geologic and topographic features such as characterize the Basin and Range province of the Southwest. While the geology has not been mapped in detail, the principal features have been ascertained by reconnaissances by Bryan, Ross, Wilson, Lausen, Darton, and others. Many of the ridges consist of the pre-Cambrian granites and schists of a "basal complex." In places these are overlain by sandstone of Cambrian age, limestones of Devonian and Carboniferous age, sandstone and shale of Cretaceous age, conglomerate, lavas, and sands of Tertiary age, and thick beds of Quaternary sand and gravel. Igneous rocks of various ages cut the schists and sedimentary rocks, and some of the younger granitic rocks are not very different from the pre-Cambrian granites. The sea covered much of the area for at least a part of Carboniferous time, for there are remnants of limestones of this age at many places. Outliers of Apache rocks indicate that there was deposition of sediments in the region during part of Algonkian time, the products of which may have been much more widespread than is indicated by the small remnants that are exposed. The features most striking to the traveler are mountains or knobs of schist or granite and ridges and mesas made up of a thick succession of lavas and other volcanic rocks. Many of the knobs rising above the valley floor are the summits of ranges which are now nearly buried under the thick valley fill of sand and gravel washed from the mountain slopes for a million years or more. Before the extrusion of the Tertiary volcanic matter the region presented an irregularly eroded surface, doubtless a desert, some areas of which were occupied by sands and boulder deposits of earlier Tertiary age. These deposits consisted largely of detritus from ridges and were mostly laid down by torrential streams under conditions similar to those of the present time. The lavas came to the surface through craters and cracks at various places and spread widely, probably filling broad valleys and desert flats. Doubtless some of the earlier ridges were not entirely buried. At intervals a great amount of ash, tuff, and other fragmental material was blown out of some of the vents. The succession of sheets of lavas and fragmental material is 2,000 feet or more thick in some areas, but it varies considerably from place to place in thickness and in the character and order of its rocks. The lavas were later uplifted, tilted, flexed and faulted, and widely removed by erosion, so that their original extent is not evident. Much of their detritus, together with that of older formations, makes up the thick alluvial fill of the present valleys.

The great deserts of the Southwest at first sight seem nearly destitute of animal life, but actually they are the habitat of many animals in considerable variety, most of them, however, small and not often in sight. Most numerous perhaps are the kangaroo rats, which live in large colonies in the sandy areas, but they are nocturnal, and most of their associates have the same habit. Coyotes, foxes, and bobcats frequent many localities. Various lizards and the bold little horn toad (*Phrynosoma platyrhinos*) are abundant, and in places there are rattlesnakes (see pl. 23, *A*), including the variety known as the "side-winder" (*Crotalus cerastes*), a name referring to his sidelong motion both in locomotion and attack. The rare tiger rattler lives in the rocks in out-of-the-way places, and the Sonoran coral snake (*Elaps euryxanthus*) is occasionally found. The Gila monster (*Heloderma suspectum*) (see pl. 23, *B*), a clumsy black and pink lizard a foot or more in length, is of frequent occurrence in southwestern Arizona from the San Pedro River to the Colorado. He carries poison about the teeth in his lower jaw, and his bite is fatal to small animals. The larger lizard known as chuckwalla (*Sauromalus ater*) occurs near the Colorado River, and the Indians find him as palatable as chicken. Jack rabbits and cottontail rabbits are plentiful, especially in the vicinity of the arroyos, and there remain a few of the rare antelope jack rabbits, a taller, more slender species than the common one. A few antelopes, deer, wild sheep, and lions remain in the mountains; formerly these animals were abundant, especially the antelope, but vigorous hunting has greatly reduced their number. The tortoise (*Gopherus agassizii*) roams over some of the desert areas, and his empty shell is a common sight. The average size is 8 to 10 inches. These tortoises are usually found far from water holes and evidently are not dependent on water. This is true also of the other desert animals, which obtain from plants the small amount of water that they need. Experiments made with desert mice appeared to prove that they will not drink water at all. Quail are abundant in most seasons, and doves thrive in the irrigated areas and near water holes. Cranes and similar birds are found along the rivers, and crows and buzzards congregate rapidly when food is in sight. The road runner (*Eolaptes chrysoides mearnsi*) is frequently seen. It eats rats, birds' eggs, and snakes. It runs very fast and stops quickly, using the long tail as a brake. Tarantulas (large hairy spiders), centipedes, and scorpions occur in many places; though their bites or stings are painful and probably somewhat poisonous, they appear not to be fatal.

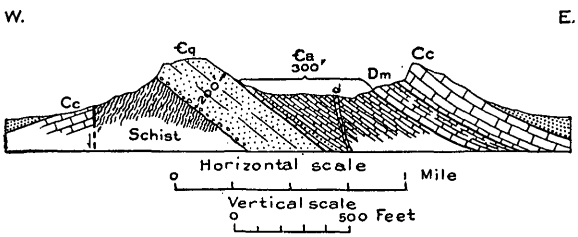
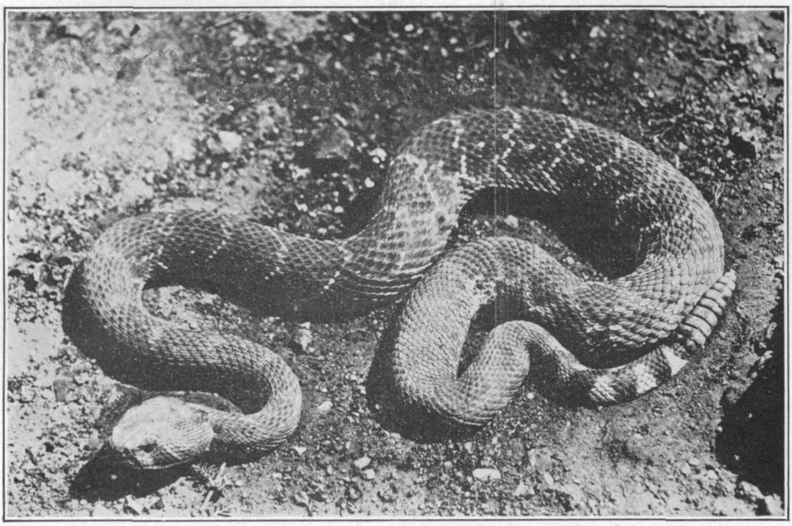


FIGURE 48.—Section at Picacho de la Calera, 16 miles northwest of Tucson, Ariz. €q, Cambrian quartzite; €a, Abrigo limestone; Dm, Martin limestone; Cc, Carboniferous limestone; d, dike

The Tucson Mountains, west of Tucson, are the Frente Negra, or Black Face Mountains, of Garcés. The range is of moderate height

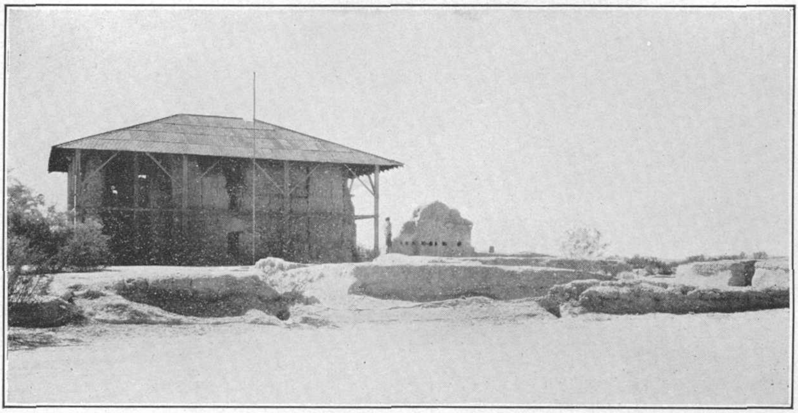


A. RATTLESNAKE

Common throughout western Texas, New Mexico, and Arizona.

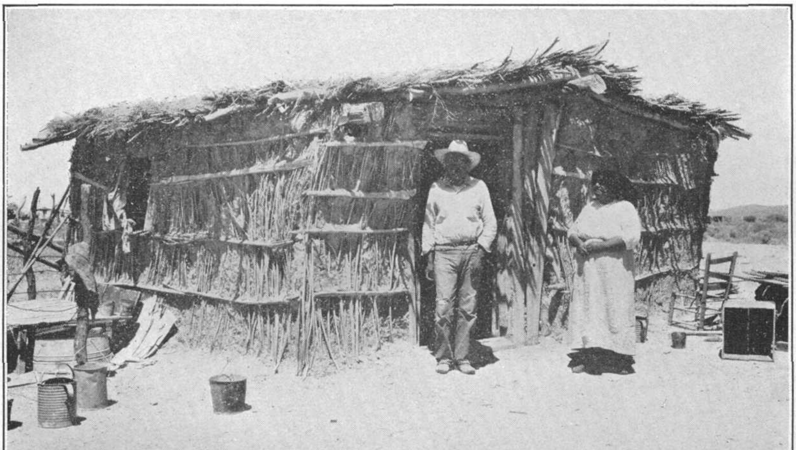
B. GILA MONSTERS

Found in many places in southwestern Arizona.



A. CASA GRANDE, ARIZ.

The ruins of a communal house of the aborigines, now under a protecting shed.



B. TYPICAL HOME OF PIMA INDIANS ON RESERVATION SOUTH OF PHOENIX, ARIZ.

and consists mostly of volcanic rocks in widely extended sheets and several stocks, erupted from craters or possibly from some cracklike vents in early Tertiary time.[40] On the east slope of the mountains is an old quarry in light-colored volcanic tuff which has been used for building one of the university buildings and many houses in Tucson.

The Tumamoc Hills, an outlying knoll of the Tucson Mountains just west of the city, consist of a succession of lava flows (andesite, rhyolite, tuff, and basalt) and several intrusive masses that are probably of Pleistocene age.

From Tucson the railroad follows the wide flat adjoining the Santa Cruz River, which has a sandy bed of many braided channels, usually dry. At times of rain the Santa Cruz carries considerable water. According to records of the United States Geological Survey the flow at Tucson aggregated 57,200 acre-feet in 1914 and 24,700 acre-feet in 1915. The Santa Cruz is an affluent of the Gila, which its channel reaches in the neighborhood of Phoenix, but even in Garcés' time it sank into the sands near Picacho Peak, and at present it rarely flows even that far. However, there is considerable underflow in the sand and gravel of the valley fill, especially below the mouths of Rillito Creek and Cañada del Oro, and this water is pumped for irrigation. The irrigated area is entered near Jaynes, a short distance out of Tucson, where there is a State experimental farm; it continues with some interruptions nearly to Naviska.

Cortaro.
Elevation 2,156 feet.
Population 80.*
New Orleans 1,511 miles.

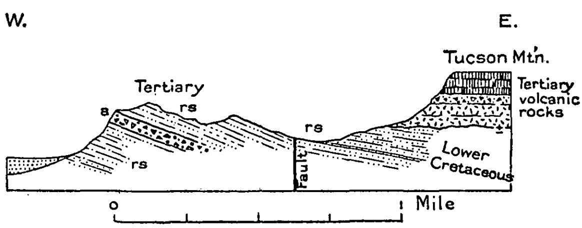


FIGURE 49.—Section of the west side of the Tucson Mountains, Ariz., about 3 miles south of the Ajo road, or 2 miles south of Amole Peak. a, Agglomerate; rs, red sandy shale

[40] Rhyolites and andesites, in part porphyritic, are the principal rocks, with some tuff and basalt. Amole Peak (ah-mo'lay), the highest summit, and some other knobs consist of intrusive rhyolite. Granite and granodiorite, apparently intrusive, occur on the west side of the north end of the range. Picacho de la Calera, an outlying butte to the northwest, consists of limestones of Carboniferous and Devonian age (Escabrosa and Martin) with abundant fossils. These limestones are underlain by 300 feet of typical Abrigo limestone with trilobites and other fossils of Upper Cambrian age, and at the base, lying on pre-Cambrian schist, is 200 feet of Bolsa quartzite. The section in Figure 48 shows the relations at this place. Along the foot of the southwest side of the Tucson Mountains are extensive exposures of sandstone and shale believed to be of Lower Cretaceous age. They lie nearly level and are overlain by the Tertiary volcanic succession to the east and by a sheet of rhyolite to the west. Farther north they are faulted against a thick body of red sandy shale and arkosic sandstone with an included bed of agglomerate with much volcanic material of Tertiary age. Figure 49 shows the relations in this part of the area.

The area under cultivation is about 7,000 acres. The water is supplied by many shallow wells operated by electric power from Tucson, and there are some flowing wells. The water is carried by canals, mostly cement lined. Much cotton and alfalfa are raised, together with various other crops. Cotton is a native plant (Cabeza de Vaca was presented with cotton garments by the natives in 1535), but the wild variety gives only a small yield of the fiber. The cultivated cotton yields about a bale to the acre. The average crop in the valley requires from 20 to 24 inches of water, but alfalfa, which is cut five or six times a year, requires 36 inches. There is considerable dairying to supply milk for Tucson and other places.

Rillito.
Elevation 2,069 feet.
Population 32.*
New Orleans 1,516 miles.

Northeast of Rillito is a conspicuous range of buttes and ridges known as the Tortolita Mountains (tore-toe-lee′ta). They consist of pre-Cambrian granite and schist and rise abruptly from long slopes of gravel, sand, and other detritus. On the south edge of the range are volcanic rocks. To the south and southwest from the railroad near Naviska siding there are fine views of the rugged ridges of the Roskruge, Coyote, Quinlan, and Baboquivari Mountains, the last culminating in the square tower of Baboquivari Peak (elevation 7,740 feet), 50 miles away. To the west are the Silver Bell Mountains. These are all on the west side of the wide desert of Avra Valley, which joins the Santa Cruz Valley a short distance southwest of Red Rock. These valleys are deeply filled with gravel and sand.

From Tucson to Picacho the railroad follows the route pursued by Padre Garcés and the expedition of Captain Anza in 1775 on their long overland journey to establish a colony at San Francisco. They traveled, however, on the left bank of the stream as far as Red Rock. According to Padres Garcés and Font, the Anza expedition consisted of 30 soldiers and 136 other persons, including women and children. It followed the Santa Cruz River through Bac and Tucson. Rillito lies at the place they called Llano del Azotado (meadow of the flogged man), because a deserting muleteer taken into custody was here given 12 lashes. Passing near the present Red Rock station to a point beyond Picacho Peak, it turned to a more northerly course, approaching the Gila River about 2 miles west of Casa Grande, which the friars visited and minutely described. Several camps were made on the Gila River in this very populous Indian country, where wheat, Indian corn, and cotton were being raised. The course then swung southwestward around the south end of the Sierra Estrella across the "Dry Wash" (apparently Waterman's Wash) and through the pass in Maricopa Mountains now followed by the railroad to modern Gila Bend, a route which later became the emigrant trail. Near Gila Bend they found an Indian village, called by Padre Garcés the Pueblo de los Santos Apóstoles San Simón y Judas.

Rillito and Marana are small settlements sustained by irrigation with water pumped from the underflow of the Santa Cruz River.

Marana.

Elevation 1,994 feet.
Population 75.*
New Orleans 1,520 miles.

Red Rock.

Elevation 1,868 feet.
Population 40.*
New Orleans 1,531 miles.

West from Naviska siding the region is a wide desert. Occasional sahuaros are in sight from Avra siding and westward nearly to Picacho. The village of Red Rock is on this wide desert plain, which extends north to and beyond Phoenix and far to the west. This plain is floored with sand and gravel, in most places very deep, and the subsurface geology is not known. The embankments at intervals along the railroad in this vicinity were built for protection from flood waters. Many steep-sided mountains rise out of this plain, mostly of granite, schist, or volcanic rocks, their rugged outlines indicating rapid disintegration.[41] The valley floor bears a sparse vegetation of small mesquites and other plants, widely spaced on account of the arid climate.

A railroad branches to the southwest from Red Rock to Silver Bell, 18 miles distant, a small town with a large copper mine. The workings are in a group of high ridges, consisting in part of rhyolite and tuff of volcanic origin, and a succession of 3,700 feet of quartzite and limestone, the latter containing Carboniferous fossils (C. F. Tolman). An extensive intrusion of alaskite porphyry carries blocks of the limestone, one of which, according to Stewart, is nearly 2 miles long and 2,000 feet wide, and there are later dikes of andesite and trachyte porphyry. The ore reduction works at Sasco are visible from Red Rock. The Waterman Mountains, a small range 6 miles southeast of Silver Bell, consist of porphyry, quartzite, and a limestone that contains fossils of Permian age (Naco limestone).

Northwest of Red Rock, on the left side of the railroad, is the prominent peak known as Picacho or Saddlerock Picacho (see

[41] Rock disintegration proceeds rapidly in the desert regions of the Southwest. The great difference of temperature between hot afternoons and chilly dawns is an important agent, causing great expansion and contraction, and the frosts of midwinter are potent in aiding disintegration. Leaching of limestones and decomposition of minerals in crystalline rocks are factors which produce large results in a few centuries. Most rocks are traversed by joints or cracks, and along these disintegration progresses. It finally isolates spalls or blocks of the rock, and these fall and eventually crumble into detritus, which is worked down the slopes and becomes valley fill or is carried by freshets into and along the larger streams. Running water containing sediment in suspension is a powerful erosive agent, and wind-blown sand is especially effective in removing decomposed or soft rock.

Joints in rocks are cracks, generally not of great length, due to shrinkage in cooling if the rocks are of igneous origin, or to strains of various kinds, especially earth movements. They may run in various directions or may be arranged in sets of nearly parallel cracks which intersect other sets at approximately constant angles. Joints differ from faults in being much smaller fractures that show little or no slipping or vertical displacement of the rock along the break.

pl. 22, *B*), which becomes conspicuous near Avra siding and is a landmark for many miles in all directions. Its elevation is 3,374 feet. It consists of lavas steeply tilted to the north, and it may also include the neck or vent of an old volcano. The railroad passes very near this peak at Montrose and Wymola sidings. According to Garcés, it was called Cerro de Tacca by the Indians. Near it, in ancient days, was a Pima settlement or ranchería called Akutchiny ("mouth of the creek"), located at the sink of the Santa Cruz River.

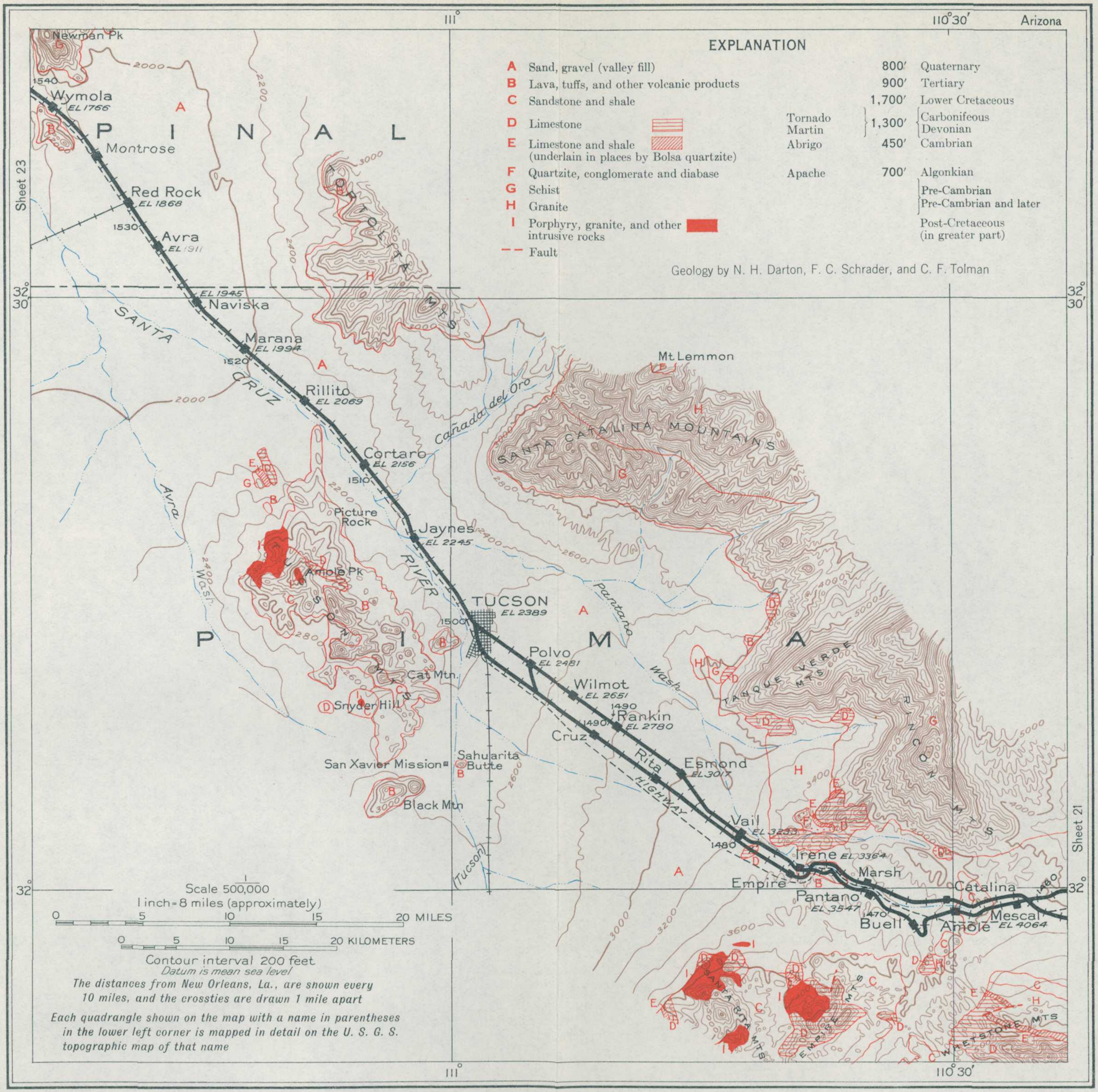
Wymola.
Elevation 1,766 feet.
New Orleans 1,538½ miles.

In the pass a few rods east of Wymola siding there is a 10-foot monument just south of the tracks with the inscription "Lieut. J. Barrett and Privates G. Johnson and W. S. Leonard, killed April 15, 1862, in the only battle of the Civil War in Arizona. Erected by the Arizona Historical Society and Southern Pacific Railway, April 15, 1928." These men and a few others, members of the California Volunteers, had an encounter with Confederates who had just evacuated Tucson.

The Picacho Mountains, a high rocky range rising out of the desert plain north of Wymola, culminate in Newman Peak (elevation 4,529 feet). They consist of schist, all of which in this general region is believed to be of pre-Cambrian age.

Beginning near Wymola and extending for about 5 miles west is a very fine assemblage of cacti, growing mostly on the rocky slopes along the south side of the railroad. There are many stately sahuaros, barrel cactus (biznaga), cholla (cho'ya), and other desert species.

The region extending west from the San Pedro River to the Colorado River and the Gulf of California, constituting the northern part of the Province of Sonora, was known to the early explorers as Pimería Alta (pe-may-ree'ah). When the Spaniards found that its northern and northwestern extension was occupied by the Papago Indians they called this portion Papaguería (pa-pa-gay-ree'ah), to distinguish it from the region of the more sedentary Sobaipuris of the Santa Cruz and San Pedro Valleys. With a mean annual rainfall on the lower lands ranging from 3 to 10 inches and a mean annual temperature of 67° at Tucson and 72° at Yuma, it is one of the warmest and most arid portions of the United States. In places the summer maximum temperatures are as high as 126°. The vegetation is a striking assemblage of peculiar plants in which large cacti, small desert trees, and many shrubs are present, but all widely spaced. No part of the region is so dry as to be without plants except a few areas of drifting sand. Where the ground water is near the surface, as in the wider plains subject to occasional flooding by rains, there is considerable mesquite, but this plant also grows in many places where the amount of water is very slight for most parts of the year. Mesquite, like a few other desert plants, has a very long tap root that penetrates to



Topography: U. S. Geological Survey quadrangle maps

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sands containing some moisture, and also a system of wide-spreading lateral roots that quickly absorb water near the surface when there is rainfall. Creosote bush, iron wood, paloverde, ocotillo, grasses, and scattered cacti of several kinds are the more noticeable plants in the valleys and along the dry mountain slopes.

The topography is of the Basin and Range type, with high, bare rocky ridges, mostly narrow, separated by wide, flat valleys. The larger features trend north and south, although there are many local exceptions to this trend. The valleys range from about 3,000 feet above sea level in the northeast to 250 feet in the Yuma Desert. The mountains are bare and desolate, and the broad desert valleys with terrifying scarcity of water seem formidable to travelers. For many persons, however, the region possesses an intense interest and charm—often referred to as the lure of the desert.

MAIN LINE, PICACHO TO PHOENIX AND WELLTON, ARIZ.

Picacho.
Elevation 1,621 feet.
New Orleans 1,545 miles.

The line from Picacho to Wellton by way of Phoenix (turn to sheet 23) was built in 1925 and 1926 at a cost of $15,600,000, in order to pass through the great irrigation district of the Gila (he'la) and Salt Rivers. It is 42 miles longer than the old line but has the advantages of better grades, fewer curves, and long tangents, which almost compensate for the detour. The Gila River is crossed twice, one bridge being 5,000 feet long and the other 3,800 feet.

Coolidge.
Elevation 1,425 feet.
Population 1,100.
New Orleans 1,564 miles.

This route leaves the old main line at a switch tower a mile west of Picacho siding and goes north across the wide alluvial plain to the Gila River, 20 miles distant. It passes through the sidings of Peak, Topaz, and Randolph and the town of Coolidge in this interval and also crosses the great ditch that carries water from the Gila River to Casa Grande and other irrigation settlements to the westward. This water conserved by the Coolidge Dam, on the Gila River in the mountains 50 miles above Florence, is let out into the river as required and deflected into the main canal near Florence. (See p. 210.) About 40,000 acres of the land to be irrigated is in the Gila River Indian Reservation, and the remainder of the water is available for settlers outside, who have taken up much of the land and are raising cotton, lettuce, and other crops with satisfactory results.

Two miles beyond Coolidge the ruins of Casa Grande are in sight, not far west of the railroad. For many years they had no protection against the weather, but finally after some restorations a roof was erected to protect the ruins from rain and in some measure from wind-blown sand, a powerful erosive agent in regions of dry climate. (See pl. 24, *A*.)

Casa Grande,[42] as the name indicates, is the "large house" mentioned by the early explorers; it was the work of aborigines of 700 to 1,000 years ago. It was discovered by the Jesuit Padre Kino in 1694; he reached it again by way of the San Pedro in November, 1697, and said mass within its walls. It stood 1½ miles south of the Gila River, with which it was at that time connected by a wide ditch. It was visited by Padres Garcsè and Font in 1775 and minutely described by Font. It has always been one of the best preserved of the prehistoric ruins and has been restored to a considerable extent by the United States National Park Service, which took possession of it in 1892. There were three buildings within a space of 150 yards, two of which were practically ruined. The walls of the main building, which was three and in the central part four stories high, were massive and 4 or 5 feet thick at the base. The inner sides of the walls were vertical, but the outer sides sloped inward in a slightly curved line. The house contained 11 rooms and had a watchtower estimated to have been 39 feet high. The material used was the local mud and gravel packed into rectangular blocks until hardened. There is some ornamentation in red on the inner polished walls, but no inscriptions. There are doors east and west, but no windows except circular openings in the upper part of the chambers. The framework of the building evidently was burned, presumably by hostile Apaches. Near by are ruins of other buildings and of an elliptical amphitheater more than 100 feet long, probably all used for religious or communal ceremonies.

Excavations in 1930 a mile east of the Casa Grande ruins revealed several large houses, several crematory pits, and much pottery, carved bone, and stone and shell artifacts. Fragments of mirrors whose reflecting surface was a close mosaic of iron pyrite crystals were also found, showing that the people took considerable interest in their personal appearance.

In the river flat just north of the ruins are remains of old irrigation ditches which conveyed river water to fields. The people of this early settlement were evidently experienced in agriculture, and the irrigation ditches, some of them large, show considerable engineering skill. (See p. 201.) It seems clear from the broken pottery and ruins that the Gila Valley and the valley of the Salt River supported a good-sized agricultural population in the early days. The Pima Indians called these people "Hohókam." They lived in small huts not unlike the Pima "jacales," made of rude masonry. It is supposed that they came from the south. It is an Indian tradition that a hostile faction from the east drove these agriculturists from their settle-

[42] It has been suggested that this may be the ruined house called "Chichiltiécale" (red house), where Coronado changed his course from north to northeast on his way to the Seven Cities of Cibola (Zuñi) in 1540, but many authorities believe that his route was farther east. (See p. 161.)

ments in the Gila Valley, but some who remained in the general region were the ancestors of the Pima, Papago, Yuma, Chemehuevi, Mohave, and Maricopa tribes of the present day.

In the times of the Conquistadores and the missionaries most of the sedentary Indians of Papaguería lived on adjacent ranches and in villages palisaded for protection against roving Apaches or other enemies. It is stated that there were about 6,000 of these Indians and 100 rancherías in the lower Gila region in 1742. There was constant warfare among the tribes or among allied tribes. For the white man there seems to have been a hearty welcome until ill treatment roused hatred that prevailed for a long time. The Pima Indians, however, have always been friendly to the white settler and helped to fight the Apaches, who were hereditary enemies of the sedentary tribes, stealing their crops and wives. Now Papago, Maricopa, and Pima Indians live in harmony on the reservations south of Phoenix. The Pimas and Maricopas have the first rights on the irrigation waters of the Gila River, which they use extensively for the more common field crops.

The lower Gila region was never the scene of such extensive and bloody Indian warfare as other parts of Arizona, because of the more peaceful character of its aboriginal inhabitants and partly because of the scarcity and poverty of the white settlers in the early days.

Two miles north of the Casa Grande ruins the broad bed of the Gila River is crossed on a long bridge. In the main channel there is usually considerable water, which is allowed to flow from the Coolidge Reservoir to sustain irrigation, together with some ground water and seepage of local origin. The Gila River is one of the major streams of the Southwest, for it drains an area of about 7,200 square miles and is about 500 miles long. It rises in western New Mexico and crosses all of Arizona to join the Colorado River just above Yuma, receiving many large affluents, including the San Simon, San Pedro, and Santa Cruz Rivers, which are crossed by the railroad in eastern and central Arizona. Up to 1853 (the time of the Gadsden Purchase) the Gila River was the boundary between the United States and Mexico. The Gadsden Purchase brought into the United States the portion of Arizona south of the Gila River, an area of 40,000 square miles (see map, p. 151), at a cost of $10,000,000. The international boundary was surveyed in 1855, and the United States took possession in 1856 by sending troops to Tucson. The river was called Río del Nombre de Jesús by Oñate in 1604. The heroic Father Kino in 1694 applied the name Rio Grande de Gila to the river, but generally called it Rio Grande. The Indians on its headwaters were called Xila or Gila, and this name was applied by the Spaniards to a savory but bony fish called matalote by the Indians. It is stated also that there is a Yuman word Hila, meaning salty stream. Later, Kino's name was given to the entire stream.

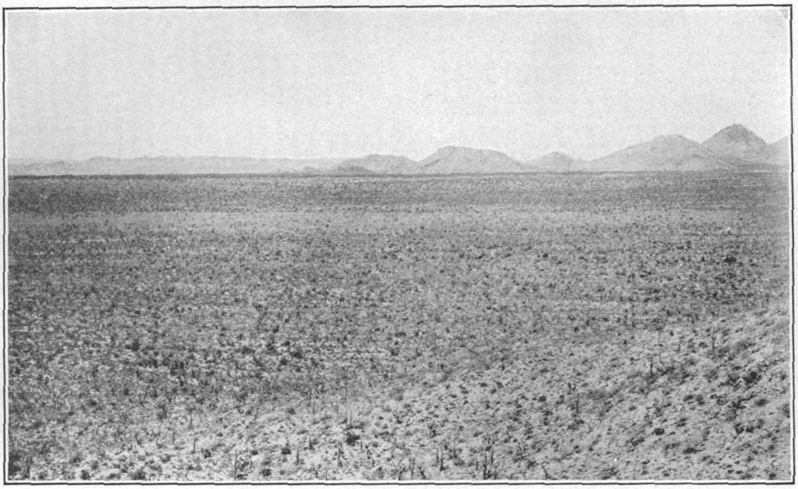
After crossing the Gila River to Poston siding, near which a branch line leads to Florence, 6 miles east, and thence to the mining town of Christmas, in eastern Pinal County, the railroad deflects northwestward and follows near the north bank of the river through Blackwater and Olberg sidings. To the east and north of the railroad are many buttes of granite, the highest of which, Walker Butte, is capped by lava. At Olberg is a quarry in lava and scoria, which are used extensively for road making.

North of Olberg is Malpais Mountain (mal-pah-ees′), which consists of lavas and tuff [43] capping granite which appears also in ridges and detached buttes to the east; it also constitutes Santan and Goldmine Mountains, farther north. Yellow Peak and Rock Peak, a few miles north of Olberg, are capped by conglomerate of Tertiary age.

South of Olberg are the prominent granite ridges of the Sacaton Mountains, with various outlying buttes. These are all typical desert mountain ridges, with steep rocky surfaces rising abruptly from the long, gentle slopes of wash and valley fill, which is very thick in the adjoining valleys. At most places large parts of the flanks of these mountains are buried by detritus and only the tops protrude, and doubtless there are many others that are entirely buried. If this valley fill were removed the Salt River-Gila plain would present a very rugged topography, with ridges and buttes 1,000 to 2,000 feet high. The filling has progressed for centuries, is still actively going on, and will continue until the present ridges and buttes are worn very low and the smaller ones buried entirely. A view of a typical desert valley in this region is given in Plate 25, *A*.

Just south of Olberg is a dam that diverts water from the Gila River into canals to supply the lower portion of the Gila River Indian Reservation. This reservation occupies a wide area in the Gila Valley and according to the report of the United States Commissioner of Indian Affairs for 1932 contains about 4,000 Pima Indians, 500 Maricopa Indians, and a few others. Many of these Indians irrigate farms, using the water provided for them by the Government and raising alfalfa and other crops which under irrigation flourish in the rich soil of the valley lowlands. In Padre Garcés' time (1775) the largest Pima settlement was located in this immediate neighborhood, with a population of about 5,000. He called it Sutaquison, but Padre Kino 80 years earlier had named it Encarnación.

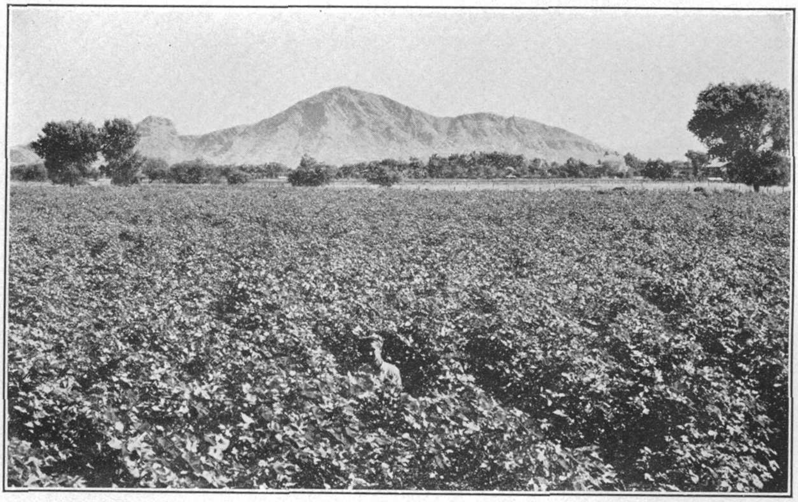
[43] These volcanic rocks cover an area of about 9 square miles and consist of several flows, in all several hundred feet thick, dipping gently south-southwest. At one locality a sheet of olivine basalt is exposed lying on a 200-foot sheet of latite, in part tuffaceous, which in turn lies on the old granite. Under the microscope the latite is seen to consist mostly of volcanic glass crowded with microliths; it contains some orthoclase, albite, biotite, and olivine.



A. TYPICAL DESERT PLAIN WITH RIDGES, WESTERN ARIZONA
Sahuaros in foreground.

B. INDIAN PICTOGRAPHS NEAR SACATON, ARIZ.
Crude figures of animals, snakes, birds, etc., depicting records or messages. Probably very old.

A. DATES IN SALT RIVER VALLEY NEAR MESA, ARIZ.



B. COTTON RAISED BY IRRIGATION IN SALT RIVER VALLEY NEAR PHOENIX, ARIZ.

Camelsback Mountain in background.

Leaving the bank of the Gila River near Olberg the railroad skirts the rocky slopes of Malpais Mountain and passes through Dock and Santan sidings. There are many sahuaros, or giant cacti, and cholla (mostly *Opuntia bigelovii*) on these slopes. Indian houses are in sight at many places (see pl. 24, *B*), and the Pima Indian village of Santan, with a large school, is a mile east of Dock siding. Three miles south of Dock is the larger settlement of Sacaton, with the Indian agency that administers the Gila River Reservation.[44] The reservation consists of 371,422 acres of which a small part is under irrigation. Now that water of the Gila River is conserved by the Coolidge Dam a much larger area can be cultivated than formerly. Near Sacaton is a field station of the United States Department of Agriculture investigating the crop conditions of the region.

East of Santan is a group of rugged ridges and hills culminating in a peak 3,093 feet high known as Santan Mountain, which is a conspicuous feature from the wide desert plain to the north. This mountain and the surrounding ridges consist of pre-Cambrian granite and schist cut by younger granite.

Near the Maricopa-Pinal county line the railroad bends due north and goes through Chandler to Mesa.

Near Serape siding the Salt River Valley is entered, consisting of almost continuous irrigated fields in a high state of cultivation, utilizing water from the Salt River conserved by the Roosevelt Reservoir. (See p. 214.) The contrast between desert conditions and vigorous plant growth is strikingly shown on the margins of the irrigated areas, especially at the foot of slopes of the rocky ranges rising out of the plain. The use of Salt River water for irrigation dates back to an early time, for the aborigines had many ditches, some of them of considerable size and length. These and the later ditches of the white man were washed out or damaged every few years by floods, which are especially prevalent in the arid region. In 1877 many settlers began coming into the valley, and since that time its development has been rapid as irrigation has been improved and extended.

Chandler.

Elevation 1,215 feet.
Population 1,378.
New Orleans 1,597 miles.

Chandler, in the southeastern part of the great Salt River irrigation district, is an attractive rural settlement founded in 1912 by Dr. A. J. Chandler. It is also a noted pleasure and health resort with an artistic winter hotel. From Chandler and northward there are fine views of Four Peaks, the high summit of the Mazatzal Range, and of the bold west front of Superstition Mountain.

[44] The Pima agency also administers the Gila Bend and Chiu-Chiuschu Reservations, occupied by small groups of Papagos. Many of the Indians are engaged in farming or serve as laborers on ranches in the adjoining regions. About one-quarter of them speak English, and many speak or understand Spanish.

Mesa.

Elevation 1,245 feet.
Population 3,711.
New Orleans 1,604 miles.

Mesa was started in 1878 by a colony of 77 Mormons who followed the original Mormon colony from Utah, established the preceding year at Jonesville (now Lehi) by Brigham Young. The new colony at once commenced the construction of a ditch costing $43,000, to irrigate about 5,000 acres. At present there is a very large area under irrigation and many crops are produced, including dates (pl. 26, *A*) and citrus fruits. From a small village in 1883 Mesa has grown to an area of 1 square mile, parts of which are closely built. The near-by population is about 11,000. The Mormons have a large temple, several churches, and an auditorium.

Two miles west of Mesa is a 160-acre farm of the State Agricultural Experiment Station, where practical tests of many kinds are made on a tract of heavy silt-loam soil, which is typical of much of the Salt River Valley. Here cotton, alfalfa, lettuce, melons, and other plants are grown under various conditions of irrigation, fertilization, crop rotation, and cross breeding. Experiments are also made with cattle and sheep pasturing.

In this vicinity are fine views of the west front of Superstition Mountain, 20 miles east of Mesa. (See pl. 31, *B*.) It consists of flows of lava (rhyolite) and beds of white volcanic tuff, in all more than 3,000 feet thick, yet greatly eroded from its original size and extent. On its slopes are many sahuaros and other desert plants, and in early summer the showy scarlet flowers of *Beloperone californica*, which also grows on the Picacho Mountains, and is very attractive to humming birds.

From Mesa the railroad turns sharply west, and near Tempe (tem′pay) it deflects north on joining the branch line from Maricopa.

Tempe.

Elevation 1,159 feet.
Population 2,495.
New Orleans 1,611 miles.

At Tempe is the State experimental date farm, the United States Entomological Laboratory, a large normal school, and a condensed-milk factory which utilizes much of the product of dairying, now a great industry in the Salt River Valley. Tempe, established in 1870, is the second oldest town in the valley. It was first called Haydens Ferry and later renamed for the classic Vale of Tempe.

At Tempe a great bridge carries the railroad over the Salt River. This large stream rises in the mountains of eastern Arizona and flows into the Gila River about 15 miles southwest of Phoenix. Formerly it experienced many freshets, with disastrous results to irrigation ditches and near-by fields, but these no longer occur since its waters have been impounded by the Roosevelt and other dams. Now its flow is regulated to meet the needs of the farms and orchards it irrigates, and its utilization has resulted in an agricultural development which has made the Salt River Valley a celebrated garden spot. Kino called the river Río Azul, and Garcés Río de la Asunción.

Just east of the bridge over the Salt River is Tempe Butte (see fig. 50), a prominent landmark due to a heavy mass of lava (andesite) lying on shale and sandstone, which with the lava is tilted to the southeast at an angle of 45° or more. The base is a massive sandstone quarried to some extent for building. The strata are more and more mixed with clay toward the top, where most of the material under the lava is red shale. More red sandstone in massive beds is exposed north of the river opposite Tempe; it grades down into a coarse granitic arkose or breccia lying on an irregular surface of old granite. It dips 65° NW., nearly at right angles to the dip of the exposure in Tempe Butte. This sandstone was found in a well 1½ miles northeast of Tempe, but a well 2½ miles northwest of the town was entirely in granite. Similar arkose and conglomerate lie on granite in Camelback Mountain, near Phoenix. Probably the age of the formation is late Tertiary. (Lee.) Other buttes, including Bell Butte,[45] rise out of the valley a short distance southwest of Tempe.

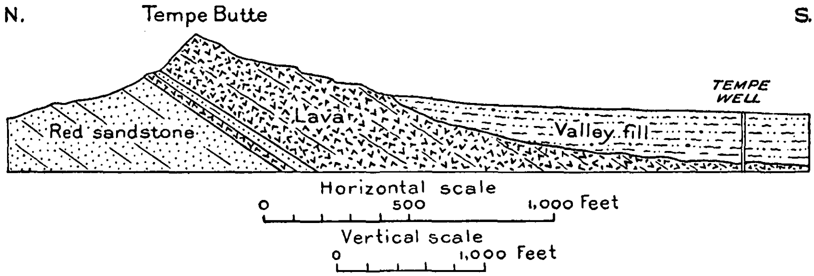


FIGURE 50.—Section through Tempe Butte and Tempe Well, Ariz. After Lee

Just north of the river north of Tempe sedimentary rocks of Tertiary age form a small group of picturesque hills included in the Sahuaro National Monument. Here the material is an arkosic conglomerate in massive beds lying in part on granite gneiss and in part on a porphyritic felsite. The conglomerate contains much granite and some schist and felsite with many fragments from 6 inches to 6 feet in diameter. In places there is but little matrix, but in general the coarse material is embedded in sand composed of grains of quartz and feldspar. It has been suggested that these rocks are of Triassic age, but here, as in Tempe Butte, they include a thin basalt flow and are capped by basalt, a succession closely resembling that which is found in the Tertiary of the surrounding region. The tilting of the Tertiary beds here and elsewhere in the Phoenix region shows that there have been earth movements in this region in post-Tertiary time, and the similar tilting and faulting of the volcanic succession in

[45] The rock of Bell Butte under the microscope proves to be a hornblende-pyroxene andesite showing phenocrysts of hornblende and feldspar of the soda-lime group. The groundmass is glassy, in part microlithic. (Lee.)

adjoining regions indicate that deformation was widespread in southwestern Arizona.

In the Sahuaro National Monument are many fine sahuaros and other plants of the desert flora which will be preserved under Government supervision. The rocks are eroded in many fantastic forms, one of which is the natural window called "Hole in the Rock." The gravel-covered plains surrounding the hills are typical of the wide desert valleys of the Southwest.

Phoenix.

Elevation 1,083 feet.
Population 48,118.
New Orleans 1,620 miles.

Phoenix, the metropolis of western Arizona and capital of the State, occupies an area of about 10 square miles on the plain extending north from the bank of the Salt River. Although in the midst of a desert, the city has developed great landscape beauty and many cultural and educational resources. It was established by Jack Swilling in 1867 as a colony for irrigation, a fact commemorated by the Swilling memorial fountain in the courthouse grounds. Phoenix was incorporated in 1881. It was reached by a branch line from Maricopa, on the Southern Pacific Railroad, in 1887 and by a branch from the Santa Fe lines (Santa Fe, Prescott & Phoenix Railroad) from Ash Fork in 1886. Prescott was the State capital from 1864 to 1867 and 1878 to 1911, and Tucson from 1868 to 1877. The Phoenix region was first visited by Padre Kino in 1694.

The growth of Phoenix has been rapid, especially since 1910, when it population was only 11,134; the growth was 70 per cent from 1920 to 1930, and this increase was closely paralleled by the growth of the populous surrounding ranch territory. The name Phoenix (given by Darrel Duffa) refers to the fact that the settlement has "risen from the ashes of the vanished civilization of the aborigines of long ago." In the valley there are many miles of ditches of great antiquity, capable of watering many acres. There are also ruins of numerous settlements and many remnants of utensils and implements. Large collections of archeologic material are on exhibition in the Arizona Museum in Phoenix and also in the Heard Museum. At the latter are collections from the ruins of "La Ciudad" or the "Indian mounds" near the city. At Phoenix there is a large Indian school sustained by the United States Government.

Irrigation has gradually been extended over level lands of the Salt River Valley until now a large area is occupied by farms and ranches in a state of high cultivation, connected by fine roads in greater part lined with cottonwoods and other trees. The valley population is about 150,000. Many crops are raised, including a large production of grapefruit and alfalfa, and for a wide area the region is a veritable garden, in great contrast to adjoining unirrigated lands that remain in their original desert condition, as shown in Plate 27, *A*. (See also pls. 26, *B*, and 27, *B*.) In 1929, according to the United States

Bureau of Reclamation, the agricultural products were valued at $38,000,000 from an irrigated area of 404,315 acres. Production and irrigated area have about doubled since 1920.

The development of irrigation was slow and irregular under private management, and there were many complaints of inadequacy of water supply and much conflict in respect to claims for water and canal rights. Finally the United States Bureau of Reclamation [46] reorganized the project and built the Roosevelt Dam to hold the water of the Salt River and its tributary Tonto Creek in a huge reservoir in the mountains 80 miles east of Phoenix. (See p. 213.)

In the Salt River Valley, as in most other irrigated lands in the Southwest, alfalfa is the most extensive crop, yielding from 5 to 8 tons to the acre; other forage plants are also raised, most of them giving two crops a year. The value of the cotton crop in 1929 is estimated at $12,435,000 by the State College of Agriculture, including much of the long-staple variety introduced from Egypt, for which the region is well suited. Cotton was a minor product prior to 1912, when its area was only 400 acres. The cost of producing cotton in the Salt River Valley in 1928–29, according to careful investigations by the State College of Agriculture, ranged from 8.72 to 20.46 cents (average 13.4 cents) a pound for ordinary cotton and from 17.2 to 38.8 cents (average 23.8 cents) for long-staple cotton. This included picking, which cost 1.5 and 2.5 cents respectively, and ginning, 45 cents per 100 pounds of seed cotton. The ginning is more than paid for by the value of the seed.

Cattle feeding and dairy farming have the advantage of having open pastures the year round, but a staggered system of pasturing is used to provide for regrowth of the grass. About 25,000 dairy cattle were reported in 1929. Many sheep are wintered in the Salt River Valley to be fattened on alfalfa.

The sugar mills are busy for much of the year, the cane crop coming in as the beet crop ends. Citrus fruits are extensively produced, to the number of 453,330 boxes in 1929 (Census report). The very young grapefruit trees can not be left out in winter, so they are taken up in December and placed under cover until spring. This process is called "balling," because a ball of earth is taken up with the roots. It was in the suburb of Ingleside, at the foot of Camelback Mountain,

[46] This bureau of the Government was an outgrowth of plans of Maj. J. W. Powell for the reclamation of the arid lands of the West, and it was brought into existence by the irrigation act of 1902, fostered by President Theodore Roosevelt, with the late F. H. Newell as the first director. The Roosevelt Dam was the first large project completed. Up to June 30, 1929, the Government had invested about $186,000,000 in reclamation projects in the United States (not counting interest), and the total repayments have been $36,350,000. The repayments in the fiscal year of 1929 amounted to $6,308,000 (U. S. Bur. Reclamation).

that the first orange orchard and the first olive grove in the Salt River Valley were planted. Of cantaloupes and melons the annual output is nearly 6,000 carloads, and of lettuce about 10,000 carloads. Figs and dates are important products, and other small fruits are raised in great variety and large amount.

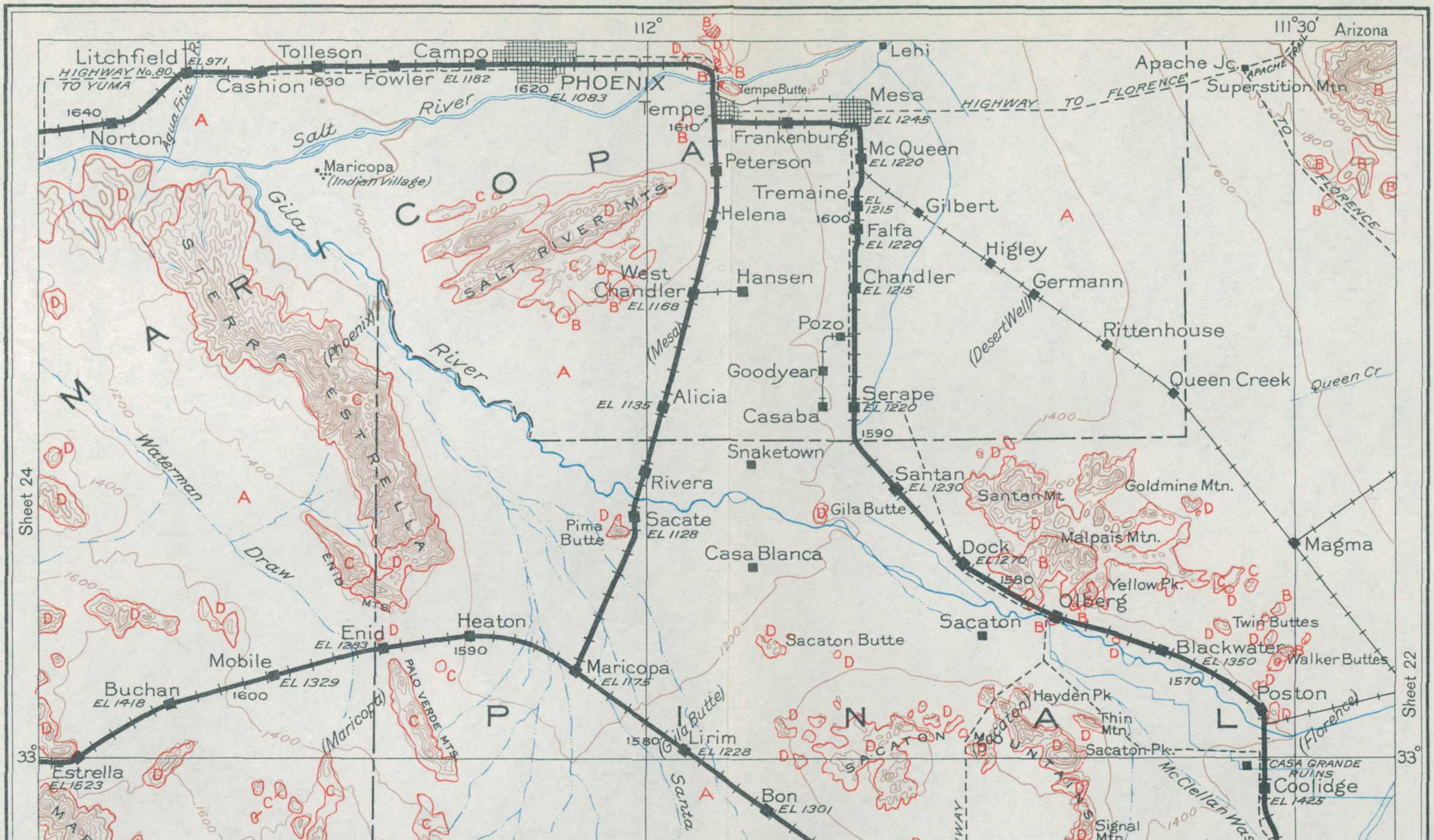
Much water for irrigation, city water systems, and individual ranches is pumped from shallow wells in the gravel and sand that underlie the Salt River Valley. These deposits contain a large volume of water, mostly the general underflow from the Salt and Gila Rivers to which is added some of the local flood water entering the valley. It is believed that although most of the rainfall is lost by evaporation or run-off, a part of it as well as considerable water that has been used for irrigation sinks into the porous material of the valley floor and in a measure replenishes the underground supply.[47] The amount of underground water available varies from place to place with the thickness and character of the permeable beds, and in some localities heavy pumping has depleted the supply. It is estimated that 525 square miles in the Salt River Valley is underlain by water-bearing beds from which the water can be profitably utilized by pumping.[48] About Mesa the area of water-bearing beds is 15 miles wide and some of them extend to a depth of 200 feet.

In the Salt River Valley as in other similar districts there are two principal kinds of alluvium—the coarse river deposits of many sorts, laid down at various stages of the rivers, in old and new channels, and under different conditions of velocity; and the finer sheet wash spread by local "cloudbursts" and by the rare long-continued rains. The coarser boulders and gravel reflect the character of the country drained, the rivers bringing materials from distant regions, the smaller streams transporting them from near-by localities. The side streams, such as Queen Creek and Cave Creek, build up broad flat fans or deltas containing a large amount of sand, gravel, and boulders, the accumulation of many freshets. (Lee.)

The thickness of the valley fill is great, at least in part of the area, for a boring 1,305 feet deep at Mesa failed to reach the bedrock that constitutes the bottom of the old valley. Doubtless much time was required for the deposition of all this material, and some of the lower finer deposits may have been deposited by lakes in late Tertiary time. It is believed that during its early stages the Salt River joined the Gila River east of the Salt River Mountains, as indicated by great

[47] The rate of underflow of waters in valley fill and other permeable material varies mainly with size of grains and head of the water. In sandstone a rate of a mile a year, or one-eighth of an inch a minute, is a fair average; in the sands of the rivers and wash deposits a rate of 2 to 3 miles a year has been estimated. (Meinzer.)

[48] A detailed study of these underground water resources was made by the U. S. Geological Survey in 1900–1903. (See Water-Supply Paper 136, by W. T. Lee.)



Topography: U. S. Geological Survey quadrangle maps

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beds of boulders underground, and at a later stage the river shifted to its present course north of these mountains. At this time it deposited the boulder beds that yield the underflow about Phoenix. These later gravel deposits lie in an old channel roughly parallel to the present one and excavated in the finer beds which were spread widely by overflows during the earlier period of accumulation.

Care has to be taken in irrigation not to let the mineral contents of the water accumulate in the soil, especially some of the well waters, which are more highly mineralized than the river water. In some parts of the valley the soil has been poisoned in this way, but this can be avoided by suitable underdrainage to carry off water that otherwise would evaporate and leave its dissolved mineral matter.

The Salt River Mountains, which rise abruptly from the desert plain a few miles south of Phoenix, consist of chloritic schist and fine-grained biotite granite. The granite is quarried to some extent as an ornamental stone. The Sacaton Mountains and many of the peaks and ridges on the east and south sides of the Salt River Valley are made up of granite, some of which is very coarse grained, with many of the feldspar crystals as much as 2 inches in length. A few miles north of Phoenix are the Phoenix Mountains, which consist largely of quartzite and other metamorphic rocks in massive beds, several thousand feet thick in all, tilted at high angles. Some of the mountains in the Salt River region are upthrust blocks; others are remnants of older ridges nearly buried by valley deposits.

The climate of Phoenix is similar to that of most of the deserts of southwestern Arizona at elevations from 1,000 to 2,000 feet. According to the records of the United States Weather Bureau, the mean annual precipitation is about 8 inches, most of which falls in midsummer showers. The amount varies greatly from year to year, however, in some years being less than 5 inches and in others as much as 14.41 inches (1911). The mean annual temperature is 70°, and the summers are long and warm, but the summer heat is much less oppressive than in regions with more moisture in the atmosphere. The amount of sunshine, as compared with the greatest amount possible, is 84 per cent. The mean temperature during the winter is about 40°, owing to cold nights, but most of the winter days are mild. Parts of the valley are free from killing frosts. (Continued on p. 218.)

DETOUR BY THE APACHE TRAIL

A most picturesque chapter is added to the transcontinental trip by the detour over the Apache Trail. (See fig. 51.) The distance is 120 miles in all and requires about one day in time and certain extra expenses for bus fare and hotel stop. This additional time and expense are well justified, however, by the superb scenery and the thrilling character of the trip.

Westbound passengers diverge from the main line at Bowie, proceeding by a branch railroad (through sleeper) to Globe and thence by auto bus to Phoenix, where the main line is rejoined. This detour is equally easy in the reverse order for eastbound passengers, who leave the main line at Phoenix and rejoin it at Bowie. The best features of this trip may also be seen by a circuit in private conveyance from Tucson over excellent highways across the highly picturesque Santa Catalina, Mescal, and Pinal Mountains, up the canyon of the Gila River to Globe and thence over the Apache Trail to Phoenix (or the reverse order). The geologic features on this line of travel are especially interesting. A comprehensive 1-day trip can be made from Phoenix to the Roosevelt Dam or even to Globe, and return, and in this trip duplication can be avoided by making the return journey to Phoenix over a perfect highway crossing the mountains from Miami to Superior and thence to Phoenix. All these trips eliminate the less interesting part of the journey, between Bowie and Globe.

From Globe to Phoenix the route is a fine highway following the old Apache Indian trail across Pinal Mountain, past the Roosevelt Reservoir, down the Salt River Canyon, through a very rugged region south of that river, past Superstition Mountain and across the Salt River Valley irrigation district. The scenery is most impressive and the geology is of great interest.

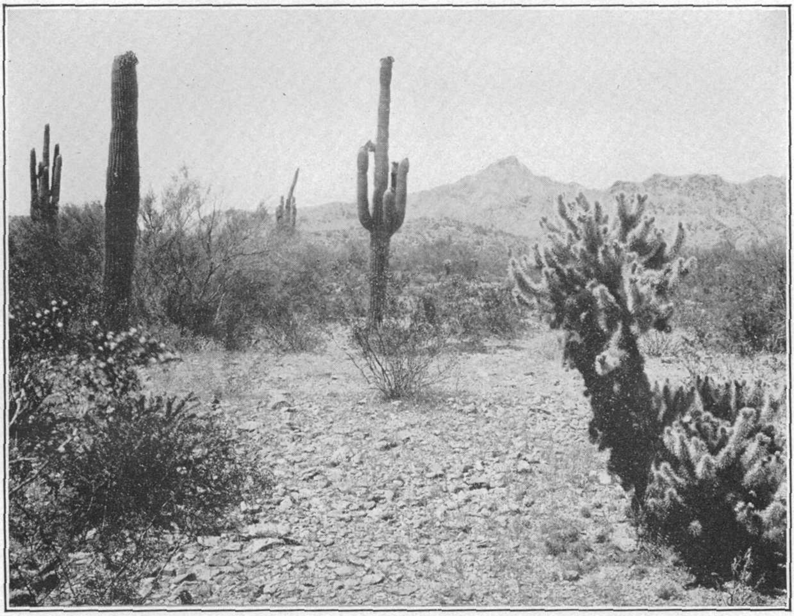
From Bowie the branch railroad descends the broad alluvial plain of the San Simon Valley to the prosperous old Mormon settlements about Safford, Solomonsville, and Thatcher. On the west is the high granite range of the Pinaleño Mountains with their culminating peak, Mount Graham, rising about 6,000 feet above the valley. On the east are the Peloncillo Mountains, consisting of a great succession of lavas and volcanic tuffs of Tertiary age lying nearly horizontal or tilted to various low angles and presenting steplike cliffs and rounded summits.

Near Solomonsville the Gila River is reached. This large stream occupies the center of a broad alluvial valley from Solomonsville to a point 75 miles northwest, where it enters a deep canyon at the Coolidge Dam. In the upper part of the valley the river water is extensively utilized for irrigation so that about Safford [49] there are wide areas of verdant fields of alfalfa, corn, and other crops, and numerous orchards and shade trees. Water is also derived from wells and from Merijilda Canyon, south of Safford. Much honey is produced. The early developments in the region were made by Mormon colonists, who had a hard struggle with Indians, floods, and other difficulties. A large proportion of the present population of the region, which is about 10,000, consists of descendants of these original settlers.

Safford.

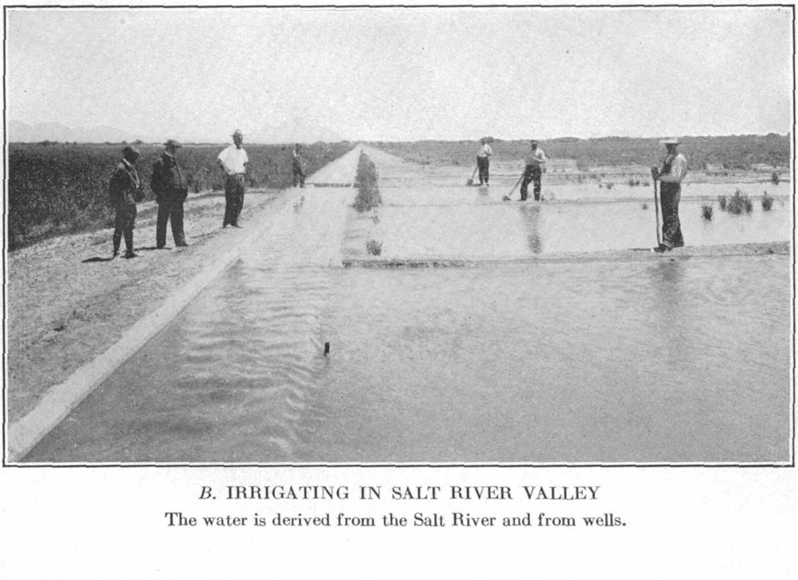
Elevation 2,923 feet.
Population 1,706.
New Orleans 1,425 miles.

[49] Named for A. P. K. Safford, governor of the Territory from 1869 to 1877.



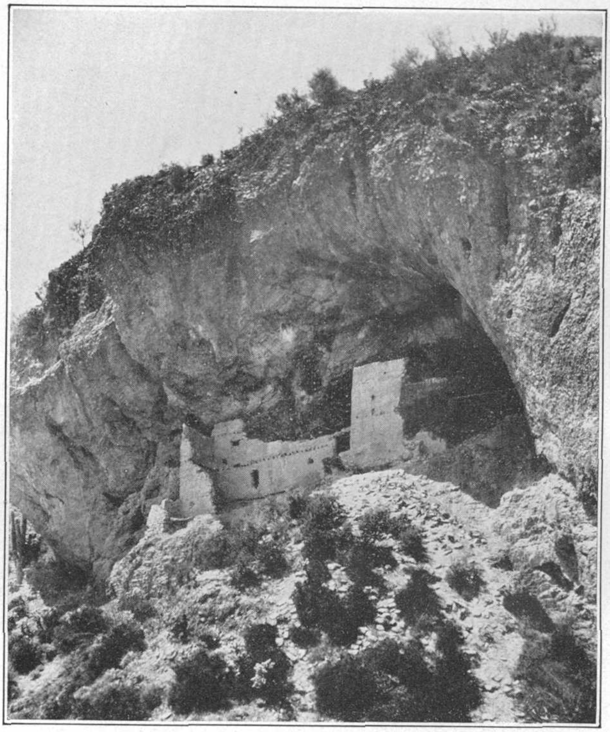
A. THE DESERT FROM WHICH THE SALT RIVER VALLEY IRRIGATION DISTRICT HAS BEEN RECLAIMED

It is covered by cacti and other desert plants and margined by bare rocky mountain slopes. Note sahuaros in fruit, also cholla at right.

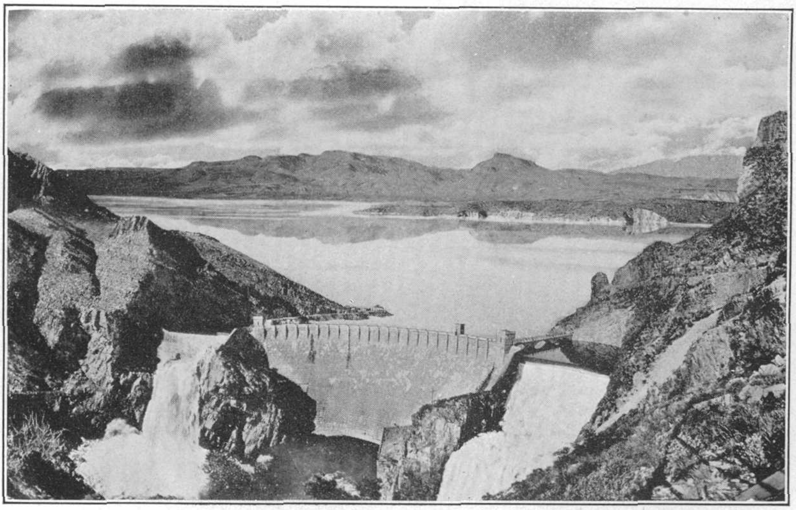


B. IRRIGATING IN SALT RIVER VALLEY

The water is derived from the Salt River and from wells.



A. CLIFF DWELLINGS, TONTO NATIONAL MONUMENT, 2 MILES SOUTHEAST OF ROOSEVELT, ARIZ.



B. ROOSEVELT DAM AND RESERVOIR, ARIZ.

Apache Trail at right; Sierra Ancha in distance; ledges of Mescal limestone and overlying strata at left.

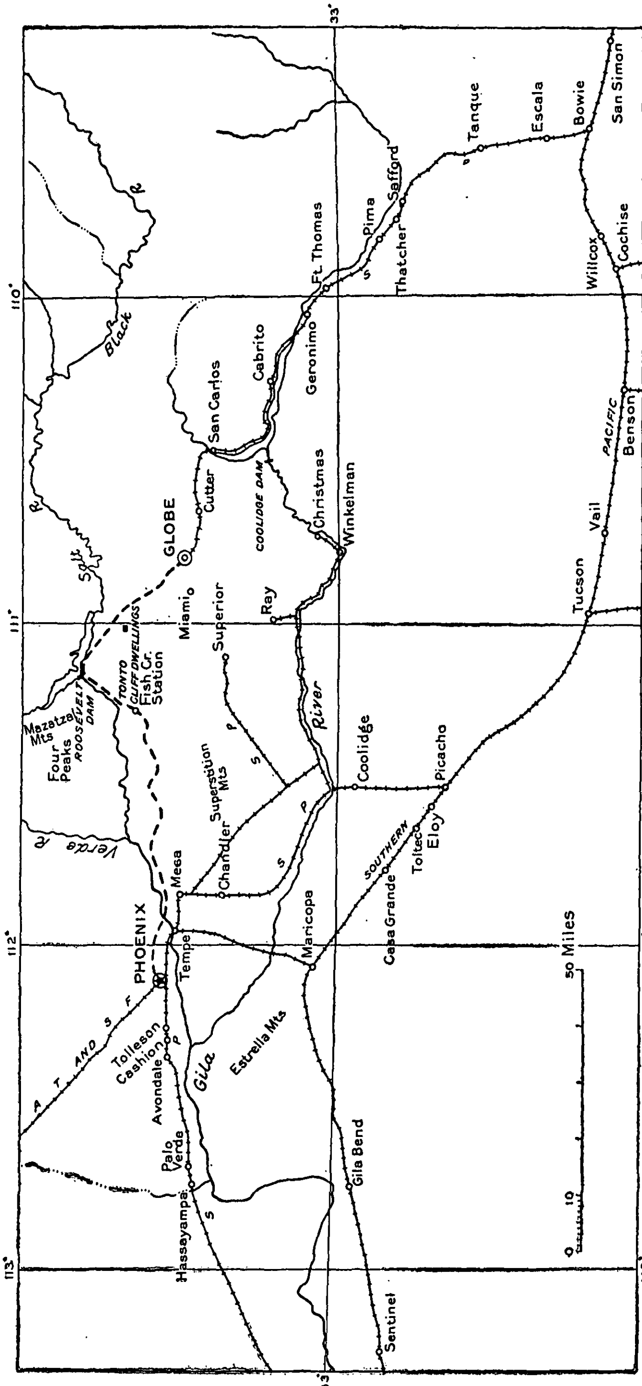


FIGURE 51.—Map showing route of Apache Trail, Ariz.

From Safford northwest the railroad follows the southwest side of the Gila River, passing through an extensive irrigation district about the towns of Thatcher, Central, Pima, and Fort Thomas. In this region are many remains of dwellings and pottery of aborigines who used the water of the Gila River for irrigation many centuries before the coming of the white man. To the north is the high ridge of the Gila Mountains, made up of great flows of lava and deposits of volcanic tuff, agglomerate, and ash extending north to the White Mountains, which were the center of eruption of a vast amount of volcanic matter in Tertiary time. To the west are many high mountains consisting mostly of granite of pre-Cambrian age. About 11 miles north of Pima are hot springs, probably rising along a fault at the foot of the Gila Mountains. At Fort Thomas was an old frontier fort. At Geronimo the route enters the San Carlos Indian Reservation, 55 miles wide and occupied by 2,715 Apache Indians, a district of valley and mountains with considerable good land along the wide alluvial flats adjoining the Gila River. The lower part of the valley in the center of the reservation, however, is flooded by the great San Carlos Reservoir created by the Coolidge Dam, which is built in a narrow canyon in the Mescal Mountains. The dam, completed in 1927 at a cost of $5,500,000, was constructed by the United States Commissioner of Indian Affairs to control water for the irrigation of the Gila River Indian Reservation and the adjoining region west of Florence and about Coolidge, Casa Grande, and Sacaton. According to the records in the office of the Commissioner the dam, which is of novel construction, consists of three domes supported by two buttresses, is 250 feet high and 920 feet long, and has a spillway capacity of 120,000 second-feet. The reservoir is about 25 miles long and in places 4 miles wide and has a capacity of about 1,200,000 acre-feet of water. This amount is sufficient to cover 100,000 acres to a depth of 12 feet, which is four times the volume required for one year's irrigation in the Casa Grande-Gila Reservation region. Below the dam is a power plant using two 7,500-horsepower turbines. This dam is barely visible from the railroad, which now skirts the north and east margins of the reservoir, but it is crossed by the highway from Bowie to Globe. At its abutments are fine exposures of eastward-dipping limestones of Carboniferous age.

San Carlos.
Elevation 2,623 feet.
Population 48.
New Orleans 1,489 miles.

San Carlos, long known as Rice, is at the confluence of the San Carlos River and Aliso Creek, two streams which also supply water to the San Carlos Reservoir. On both sides of the valley here are lava-capped mesas, and a short distance east is the old volcanic vent known as the Triplets. From San Carlos the valley of Aliso Creek is ascended. To the south are the high granite ridges of Hayes Mountain, capped in part by an extensive succession of strata of the Apache group. (See fig. 52.)

Some of the Apache and overlying limestones are exposed in cuts of the railroad 6 miles west of San Carlos. To the southwest are the Pinal Mountains (pee-nahl′), consisting of granite and schist and culminating in Pinal Peak (elevation 7,850 feet).

Passing out of the Indian reservation about 12 miles west of San Carlos, the railroad crosses the gravel-filled divide between the Gila and Salt River drainage basins and descends a short distance to Globe.

Globe.

Elevation 3,509 feet.
Population 7,157.
New Orleans 1,510 miles.

The old mining town of Globe owes its existence and sustenance mainly to the Old Dominion copper mine, the workings of which extend far under the hills on the north side of the valley, in the northern part of the town. This mine has been in operation since 1877, producing a large amount of copper, much of it from rich ore that has been smelted, as is indicated by the great terrace of black slag near the mine.[50] The ore is

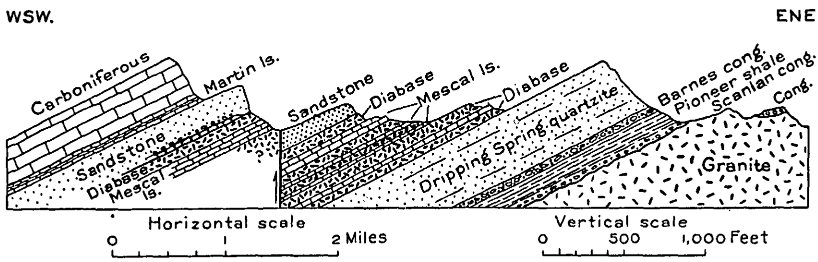


FIGURE 52.—Section across the center of Hayes Mountain, southwest of San Carlos, Ariz.

in rocks of the Apache group, especially the Mescal limestone, which are invaded by large dikes and sills of diabase intruded in molten condition in pre-Cambrian time. Lying unconformably above the Apache rocks are sandstone of Cambrian age, limestone of Devonian and Carboniferous age, and a capping of dacite, a light-gray massive volcanic rock of Tertiary age that is conspicuous on the slopes near the mine. The area is traversed by many faults. The mine is very wet; in 1928 it was necessary to pump 5,000,000 gallons a day. Part of this water is sold for use at Miami and elsewhere. There are smaller mines north of Globe which have yielded considerable copper. Globe was established in 1876 and named from a nearby mining claim. (See figs. 53, 54.)

Globe is in a region of great archeologic interest, for many remains of prehistoric structures and implements have been found here, and on the Healy terrace, on the edge of the city, an old dwelling has been uncovered.

[50] According to the U. S. Bureau of Mines the production of ore at this mine to 1929 was 415,890 tons, averaging 2.65 per cent of copper and yielding about 18,943,000 pounds of copper, together with considerable gold and silver. Most of the ore is now mined from 2,400 to 2,600 feet below the surface. According to the Mines Handbook for 1931 this mine paid dividends of $14,405,260 from 1905 to 1918 and $2,477,750 from 1919 to 1929.

From Globe busses convey passengers over the Phoenix highway, generally known as the Apache Trail. The first conspicuous feature is a ridge of gravel (old valley fill), which is crossed just south of the Old Dominion mine. The road passes about 2 miles east of the great

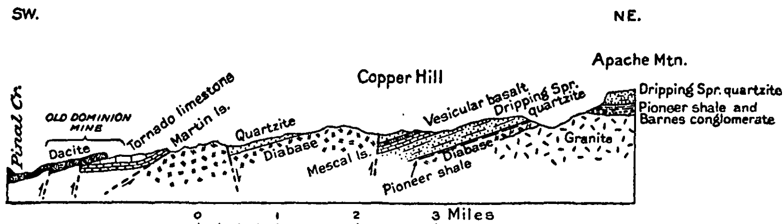


FIGURE 53.—Section of region near Globe, Ariz. By Ransome and Darton

copper camp of Miami, where copper is extracted by acid leaching from altered schists and other rocks that carry the metal in small percentage. Great piles of tailings of pulverized rock are a conspicuous feature. According to the United States Bureau of Mines,

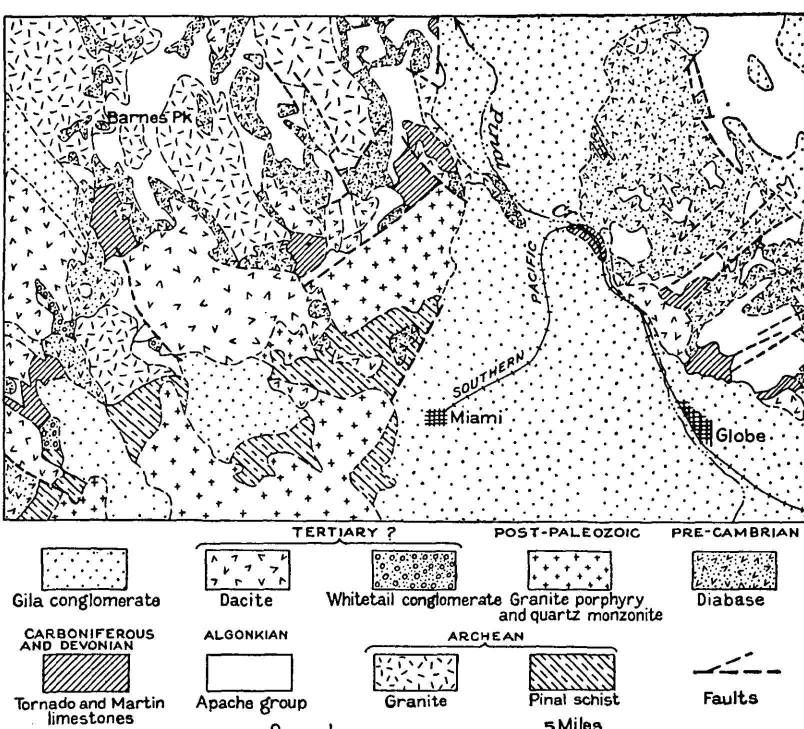


FIGURE 54.—Outline geologic map of Globe-Miami mining region, Ariz. By F. L. Ransome

in 1929 this camp produced 166,357,360 pounds of copper from 10,817,567 tons of ore in which the copper content ranged from 0.83 to 1.1 per cent. The ore here is predominantly chalcocite; that at the Old Dominion mine in Globe contains also chalcopyrite, bornite, and pyrite. The road descends the valley of Pinal Creek for some distance past outcrops of dacite lava and rocks of the Apache group broken by many faults. (See fig. 55.) Beyond the small irrigation settlement of Wheatfield the north end of the Pinal Mountains is crossed. This ridge here consists mainly of coarse granite (probably pre-Cambrian), which to the north is capped by heavy lava flows of Tertiary age. From the summit, which is in a high saddle (elevation 3,980 feet), there is a fine view of the valleys of the Salt River and Tonto Creek (tone'toe), now flooded for many miles by the Roosevelt Reservoir.

The broad old valley of the Salt River is floored and in part margined with valley fill consisting mostly of gravel and sand, part of it bedded, and some fine sediments probably deposited in a lake. The lake deposits are well exposed in badlands north of Roosevelt. As the road approaches Roosevelt there is a good view of the extensive Tonto cliff dwellings of aborigines in a deep alcove high in the cliffs about

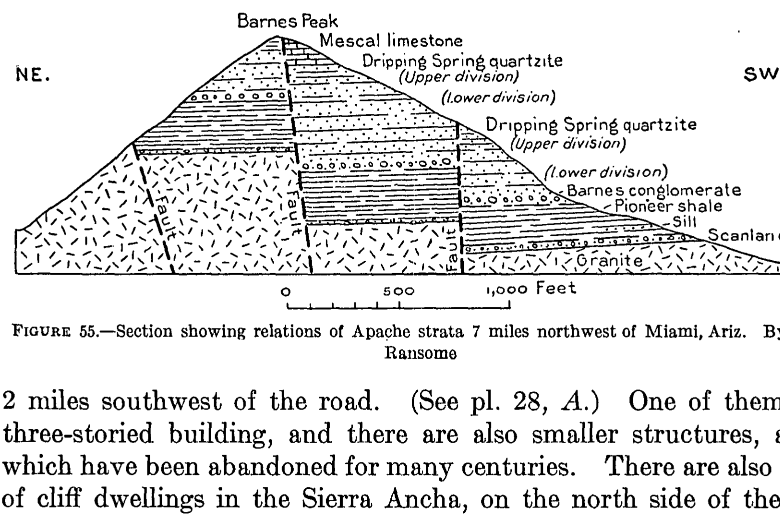


FIGURE 55.—Section showing relations of Apache strata 7 miles northwest of Miami, Ariz. By F. L. Ransome

2 miles southwest of the road. (See pl. 28, *A*.) One of them is a three-storied building, and there are also smaller structures, all of which have been abandoned for many centuries. There are also ruins of cliff dwellings in the Sierra Ancha, on the north side of the Salt River Valley. This high range of ridges and plateaus consists of a thick succession of strata of the Apache group invaded by intrusive sills of diabase, as shown in Figure 56. Certain layers of the Mescal limestone have been altered to the chrysotile variety of asbestos, which has been mined extensively for commercial use. Some of the refuse heaps at the workings are plainly visible from the road, as great white streaks high on the mountain slope. The value of this mineral varies greatly with quality. According to the Bureau of Mines the prices in 1931 ranged from $10 to $400 a ton.

A short distance beyond the small village of Roosevelt the Roosevelt Dam (pl. 28, *B*) is reached. It is built across the entrance of the long, deep canyon cut through the mountains by the Salt River just below the confluence of Tonto Creek. The Salt River rises in the mountains of eastern Arizona, where there is a moderately large rainfall and much snow. Its volume varies considerably from year to year; in 1914 the flow into the reservoir was 629,500 acre-feet, and in 1915 it was 1,440,100 acre-feet (U. S. Bur. Reclamation). Tonto Creek drains an extensive district north of the reservoir but has a much smaller flow than the Salt River. The reservoir when full is 15 miles long and from 2 to 4 miles wide and provides water for the irrigation of the Mesa-Phoenix region, 70 to 80 miles west of the dam.

This project was one of the early ones of the United States Bureau of Reclamation. At the time the work was begun in 1903 the region was inaccessible, so that roads had to be built, a cement mill erected, and a plant constructed for development of power from a canal taken out of the Salt River 19 miles above the dam site. Much of the work was done by Apache Indians. (See pl. 29, *A*.) The dam was completed in 1911 and dedicated by ex-President Theodore Roosevelt on

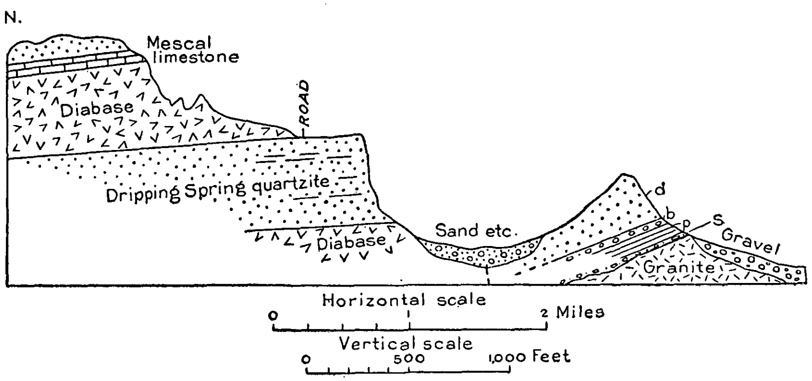


FIGURE 56.—Section through Sierra Ancha, 15 miles northeast of Roosevelt, Ariz.; d, Dripping Spring quartzite; b, Barnes conglomerate; p, Pioneer shale; s, Scanlan conglomerate

March 18 of that year. According to the United States Bureau of Reclamation it is 1,125 feet long and 280 feet high (to the roadway), with great spillways, in all requiring about 340,000 cubic yards of masonry. The power plant develops as much as 10,000 kilowatts, which is transmitted to the Phoenix region on three wires carrying 45,000 volts and with a capacity of about 21,000 horsepower. The total cost of the dam and power plant was $3,890,187. The reservoir has a capacity of 1,637,000 acre-feet. Other dams farther down the river, at Horse Mesa, Mormon Flat, and Stewart Mountain, add about 20 per cent to this capacity and treble the electric power. These features completely control the Salt River, which formerly wasted flood waters that caused devastation in the lower country. From these dams water is let out as needed, and the supply is sufficient for the irrigation of 242,000 acres. The canals and laterals aggregate 1,020 miles. About 800 rural homes in the valley are supplied with electricity. The total cost of the Salt River Valley project has been about $10,000,000.

At the dam are great rock walls exhibiting one of the finest known sections of the Apache group, which lies on pre-Cambrian granite and is overlain unconformably by sandstones and limestones of Cambrian, Devonian, and Carboniferous age. (See fig. 57.) The strata dip eastward, and the hard quartzites form the crest and east slope of a high mountain range, the northern part of which is known as the Mazatzal Mountains (mah-zat-zahl′, Indian word for red rocks). The river has excavated a canyon nearly half a mile deep across this range, which has been uplifted since the stream has flowed in its present course.[51] The range is a long up-tilted block of the earth's crust, west of which the pre-Cambrian rocks occupy a wide area, in part overlain by Tertiary volcanic rocks.

Below the Roosevelt Dam the road descends the Salt River Canyon along its south side, crossing a wide area of the old granite that under-

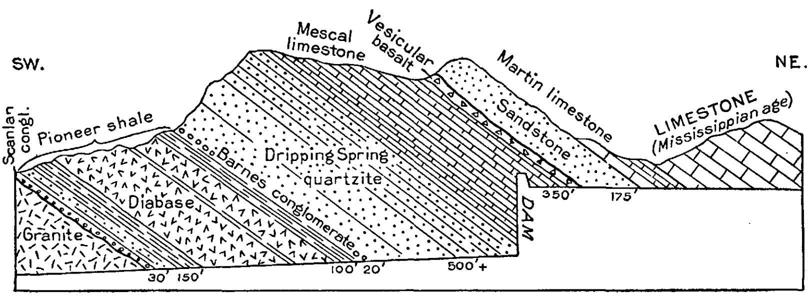


FIGURE 57.—Section at Roosevelt Dam, Ariz.

lies the Apache group near the dam. In places, especially at points a few miles west of the dam, this granite is invaded by thick dikes of

[51] The section begins a short distance below the dam and extends to the quarries southeast of the dam. The contact of the pre-Cambrian granite and the Scanlan conglomerate, the basal formation of the Apache group, is clearly exposed on the road as well as in the north wall of the canyon, a short distance below the dam. The Dripping Spring formation, next above, is a reddish quartzite, in part slabby, but so hard and compact that it makes the mountain crests to the north and south on both sides of the dam. It is invaded by thick sills of Algonkian diabase of a type distinctive of the Apache group in central Arizona and of the Unkar group in the Grand Canyon. The dam is built mainly in the Mescal limestone, which here attains its maximum thickness of 350 feet. Much of this limestone is pure, but some beds contain considerable interbedded chert in thin layers, possibly of algal origin. On the Mescal lies a sheet of lava (basalt), vesicular in large part, especially at the top and bottom, and apparently conformable. This was a surface lava flow in late Apache time. The overlying sandstone (Cambrian), about 200 feet thick, contains at the base pebbles of the lava and other rocks, and though conformable in attitude it is separated from the Apache group by a great interval of geologic time. It is overlain by limestones and sandstones (Martin limestone) with Devonian fossils, and this in turn by limestone and sandstone of Carboniferous age, which are well exposed in ledges and quarries above the dam.

diabase that doubtless were feeders of sills in the Apache group, which probably formerly overlay the granite in this area also. The sahuaro, or giant cactus, is conspicuous here and in the country to the west. (See p. 179.) The narrow depths of the canyon in this vicinity are occupied by Apache Lake, a long picturesque reservoir held by the Horse Mesa Dam, built in 1926 in a tight canyon cut by the Salt River through the rhyolite at the west end of Horse Mesa, 17 miles below the Roosevelt Dam. According to the Bureau of Reclamation the Horse Mesa Dam is 305 feet high (bedrock to top of coping) and 540 feet long. The head of 264 feet gives about 43,000 horsepower. The lake has a storage capacity of 245,000 acre-feet. The highway skirts the lake but does not reach the dam.

Six miles below the Roosevelt Dam, where the road climbs onto a high spur, and at various other points in the next few miles there are fine views of Apache Lake and its high encompassing cliffs of volcanic rocks. These rocks belong to the succession that lies in a syncline constituting the southwest flank of the Mazatzal Mountains, Horse Mesa, and the highlands south of Apache Lake. (See fig. 58.)

In this region there are many fine views of Four Peaks (elevation 7,645 feet), in the Mazatzal Mountains to the north, and of the

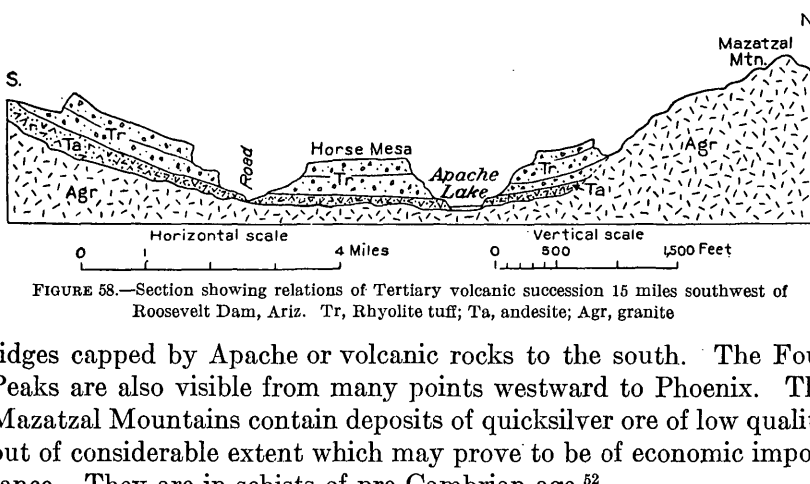


FIGURE 58.—Section showing relations of Tertiary volcanic succession 15 miles southwest of Roosevelt Dam, Ariz. Tr, Rhyolite tuff; Ta, andesite; Agr, granite

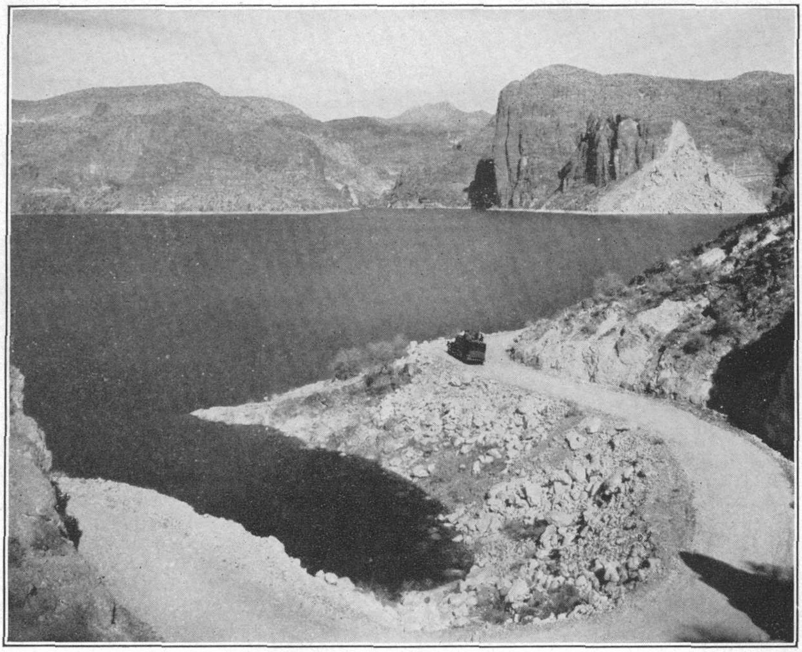
ridges capped by Apache or volcanic rocks to the south. The Four Peaks are also visible from many points westward to Phoenix. The Mazatzal Mountains contain deposits of quicksilver ore of low quality but of considerable extent which may prove to be of economic importance. They are in schists of pre-Cambrian age.[52]

About 14 miles below the Roosevelt Dam the highway crosses a low divide, leaving the Salt River Valley, and passes into the valley of a branch of Fish Creek. Here in a short distance the granite is hidden by the volcanic succession just mentioned, of which the lower members (andesite or latite) are dark gray to bright red. These are overlain by a 2,000-foot succession of light-colored tuffs, agglomerates, and lava flows (largely rhyolite), most of which are so hard and massive that they present huge cliffs. These are especially prominent on Fish Creek, as shown in Plate 30, and in the canyon of the Salt River,

[52] Ransome, F. L., U. S. Geol. Survey Bull. 620, pp. 111–128, 1916.

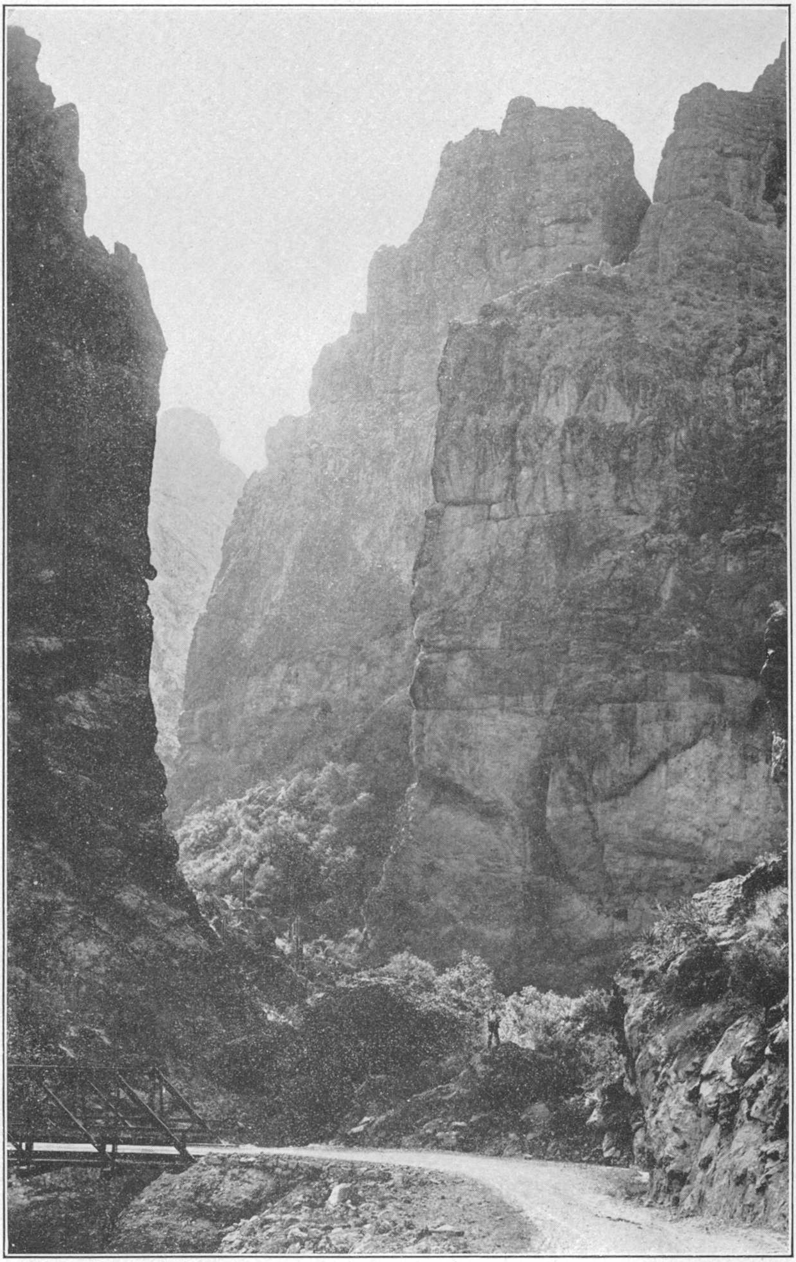
A. ENCAMPMENT OF APACHE INDIANS ON BANK OF ROOSEVELT RESERVOIR

These Indians did much of the construction work on the dam and the Apache Trail. Sierra Ancha in distance.



B. VIEW ACROSS CANYON LAKE INTO CANYON OF SALT RIVER, 35 MILES EAST OF PHOENIX, ARIZ.

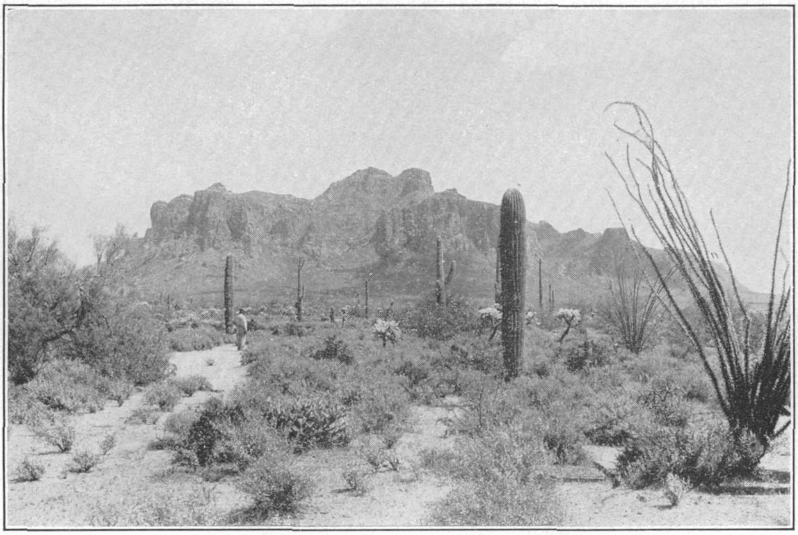
Apache Trail in foreground; Four Peaks (Mazatzal Mountains) in distance. The cliffs are volcanic tuff.



VIEW UP CANYON OF FISH CREEK AT CROSSING OF APACHE TRAIL, 40 MILES EAST OF PHOENIX, ARIZ.

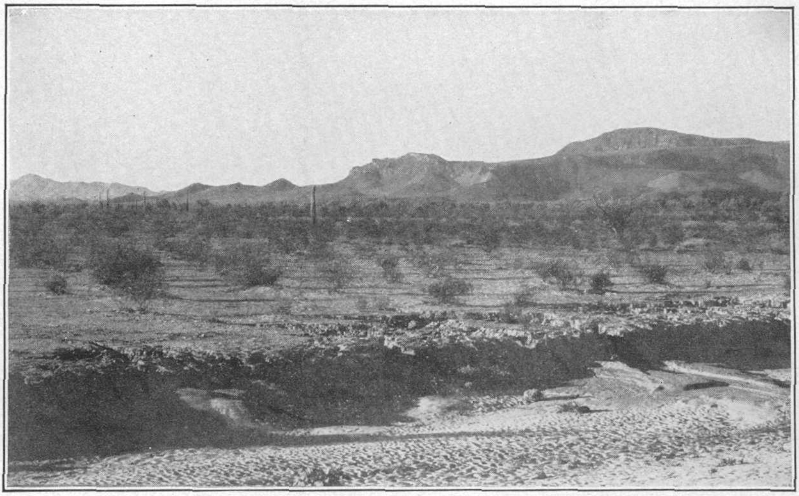
Cliffs of volcanic tuff.

A. BLOSSOMS OF PRICKLY PEAR CACTUS (NOPAL), SALT RIVER VALLEY NEAR PHOENIX, ARIZ.



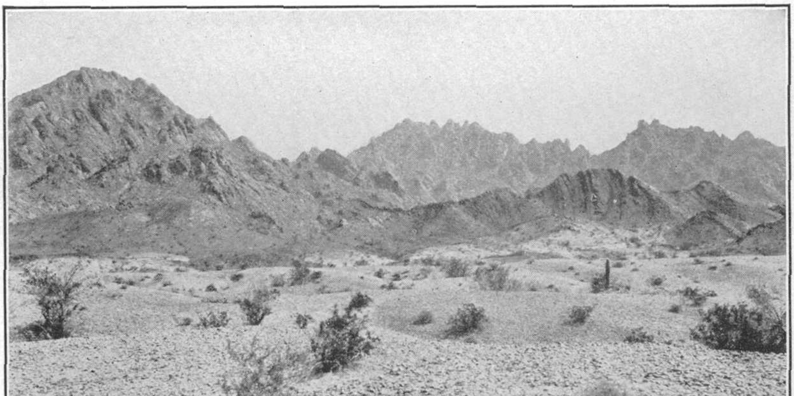
B. SUPERSTITION MOUNTAIN, ARIZ.

From point near Apache Trail, 28 miles east of Phoenix, looking east. Ocotillo on right; giant cactus (sahuaro) in center, with cholla and other typical desert plants.



A. MONTEZUMA FACE, NORTHEAST OF HYDER SIDING, ARIZ.

A remarkable profile on the mountain slope.



B. NORTHERN PART OF MOHAWK MOUNTAINS, ARIZ.

Consisting of sandstone, shale, and conglomerate of Tertiary age, steeply tilted. Looking south-southeast. (E. D. Wilson.)

both of which have cut deeply into them. There are fine exposures of these rocks on the ascent on the west side of Fish Creek, where the road climbs nearly 800 feet to gain the summit of the principal massive member, and also on the wide upland westward, which the road traverses on the divide between Fish Creek and Tortilla Creek. In a cavern called Hip Pocket, on the slopes near Fish Creek, American troops under General Crook cornered a band of outlaw Apaches and destroyed them all, in part by rolling stones onto them from the cliffs under which they were hiding.

As shown in Figure 58, the principal structural feature in this vicinity is a shallow syncline, which is plainly visible along the road for a long distance west. Tortilla Creek exposes the dark basal member of the succession. Mormon Flat, the lower part of the valley of this creek, at its junction with the Salt River, is flooded by the reservoir known as Canyon Lake (pl. 29, *B*), which is held by a dam built in 1923–1925 in a bend of the Salt River just below Tortilla Creek. The river enters the reservoir through a gap near the lower end of the wide portion of the lake. The dam is 350 feet long and 229 feet high above bedrock, which lies about 70 feet below the bed of the river. It cost about $1,257,000, and the power plant, which develops 10,000 horsepower, an additional $500,000.

The Stewart Mountain Dam, holding the Sahuaro Reservoir, is 10 miles below the Mormon Flat Dam and 7 miles north of the Apache Trail, in a narrow part of the Salt River Canyon where the river passes through walls of granite. It is 210 feet high above bedrock and cost $2,300,000 for the dam and a power system of 17,500 horsepower. The storage capacity is about 70,000 acre-feet.

From Canyon Lake the road climbs rapidly to a divide consisting of the rhyolite tuffs and lavas of the volcanic succession, dipping north at moderate angles and showing many details of the relations of various lava flows and tuff accumulations. At many places the old Apache Indian trail is visible near the road. Not far beyond the summit in Apache Gap, Superstition Mountain comes into view, a huge pile of the same volcanic succession just crossed by the road but lying nearly horizontal and on a base of granite, which is revealed at a few points. (See pl. 31, *B*.) The precipitous west front of this mountain is skirted by the highway to and beyond the old Goldfield mining camp, which has produced considerable ore. Superstition Mountain is a famous subject for photographers and painters and probably appears in more pictures than any other mountain in the West. In the foreground are usually shown the sahuaro, cholla, and some other cacti and desert plants which are conspicuous in this region. A short distance north of Superstition Mountain and visible from points near Goldfield is Weavers Needle, a sharp peak of volcanic rock. In this vicinity was the Lost Dutchman mine, reported to have had wonderful richness. Many futile attempts have been made to find it.

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Five miles from Goldfield is Apache Junction, where the highway from Florence and Tucson joins the Apache Trail, and from this point a nearly due west course is taken to Phoenix. On the way are passed several hills and ridges, consisting of granite or schist, rising abruptly out of the desert, which here is a wide plain of alluvium irrigated by water from the Salt River.

MAIN LINE, PHOENIX TO WELLTON, ARIZ.

Tolleson.

Elevation 1,100 feet.
Population 910.
New Orleans 1,631 miles.

West from Phoenix the railroad follows the wide Salt River, with its highly cultivated district of irrigated fields, through Fowler, Cowden, and Cashion sidings and the town of Tolleson.[53] At Cashion is a large power plant made conspicuous by its high stacks. In this district alfalfa, cantaloupes, head lettuce, and cotton are the principal products, and many cattle are pastured.

Litchfield.

Elevation 971 feet.
Population 250.*
New Orleans 1,636 miles.

Near Litchfield the route crosses the Agua Fria River (ah'gwa free'ah, Spanish for cold water), a stream that drains a mountain region of volcanic rocks, schists, etc., to the north in which considerable mining is done. Southeast of Litchfield is the junction of the Salt and Gila Rivers near the north end of the Sierra Estrella (es-tray'ya), a high and exceptionally rugged range of schist that extends far southward. A short distance farther east, the Santa Cruz River, when flowing, empties into the Gila River. Litchfield, Norton, and Liberty are small settlements where a considerable area of desert land has been reclaimed by irrigation. (Turn to sheet 24.) West of Liberty, however, there is a zone about 4 miles wide in which the soil appears to be too much mineralized for agriculture.

Buckeye.

Elevation 886 feet.
Population 1,077.
New Orleans 1,651 miles.

At Buckeye, on the north side of the Gila River, wide fields of alfalfa, cotton, grains, and other crops are irrigated by a canal from the Gila near the mouth of the Agua Fria. Alfalfa seed is an important product. The canal is 20 miles long and provides water for nearly 20,000 acres. Considerable water also is pumped from the underflow from the Gila River, some of the wells yielding 200 gallons a minute. An irrigation district on the south side of the valley uses water pumped from the Gila River. North of Buckeye are the rocky slopes of the White Tank Mountains, which consist of light-colored massive schists and granite cut by small dikes of pegmatite, diabase, and other igneous rocks. A few remnants of lava have been reported in this range.

The Buckeye Hills, south of Buckeye, are irregular buttes and hills of granite and schist, part of a wide area of pre-Cambrian rocks constituting an extensive land surface that probably persisted

[53] Incorporated in 1929; named for W. G. Tolleson, one of the original settlers.

through most of Paleozoic and later time. Granite appears near the river bank southeast of Liberty and Buckeye. West of Buckeye the railroad continues along the north side of the Gila Valley, passing through several sidings used to some extent as shipping points for the many ranches in the district, most of them sustained by irrigation. Just beyond Hassayampa siding the creek of that name is crossed. It drains an area of moderate extent in the northern part of Maricopa County. There is a legend widely quoted in Arizona that the veracity of persons who have quenched their thirst with the water of Hassayampa Creek can never be relied on. Thirty miles to the north is the Vulture mine, on the south slope of the Vulture Mountains, which for a time was a notable producer of silver.[54] The famous Vulture lode, discovered in 1863, yielded ore containing more than $4,000,000 in gold (Yearbook of Arizona, 1930).

Not far beyond Hassayampa, near Dixie siding, there are small areas of recent lava, and Robbins Butte and Powers Butte, on the south bank of the Gila River, are conspicuous remnants of lava. In Powers Butte the lava caps sandstone, probably of Tertiary age. Here the Gila River bends sharply southward around the west end of the Buckeye Hills, but the railroad takes a southwesterly course. Near Arlington there is a small irrigation district using river water. Alfalfa is the principal crop, and most of it is used to feed cattle. Five miles south of Powers Butte, at a point where the valley is greatly narrowed by a lava flow,[55] the Gillespie Dam impounds the river water. This dam, built by F. A. Gillespie in 1921, is a concrete structure 1,800 feet long which conserves water for the irrigation of about 100,000 acres below Gila Bend, including the Indian reservation that occupies a long strip of bottom lands northwest of the town. The geologic relations at this dam are shown in Figure 59.

From Arlington the railroad descends into the broad valley of Centennial Draw, so named because it is about 100 miles in length from the most remote portion of the basin which it drains. The

[54] The Vulture Mountains consist of volcanic rocks of Tertiary age lying on pre-Cambrian schists cut by granites and other igneous rocks.

[55] The lava that occupies the plain west of the Gillespie Dam is relatively recent and no doubt blocked the valley for a while and caused a temporary lake. Indistinct terraces in the Arlington Valley, especially on the edge of the basalt hills north of Arlington village, seem to indicate that the lake extended to that place. Probably at that time most of the water of the Gila River escaped westward through the pass in the Gila Bend Mountains. Terraces leading into the pass were doubtless formed then, for they could not have been developed by the small stream now heading in the pass. The Gila River was probably also dammed by the lava flow north of Sentinel, for the present channel is in a gap cut through the lava. The west end of the Buckeye Hills is composed of thin sheets of andesitic lava interbedded in sandy shales and conglomerate of Tertiary age. The conglomerate carries angular pebbles as much as 6 inches in length.

lower part of its course is through a thicket of mesquite. The route continues southwestward on an upgrade of about 200 feet to a pass through the Gila Bend Mountains, thus avoiding the big bend of the Gila River. On this grade there are fine views to the northwest showing very prominent buttes, peaks, and ridges of volcanic rocks rising steeply from wide desert valleys. The most conspicuous of these is Saddle Mountain, more than 2,000 feet high, which takes its name from a deep saddle-shaped depression in its top. These features mark a center of great volcanic activity in Tertiary time, with the outpouring of thick sheets of lava and a large amount of ash and tuff.[56] The sheets of these materials have been gently tilted and flexed and considerably faulted, and erosion has cut wide valleys that isolate the ridges. In Saddle Mountain the beds are broken by many faults.

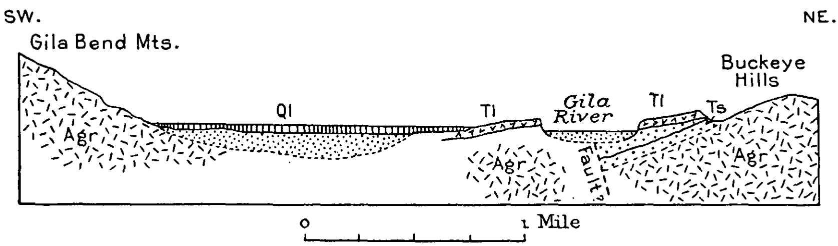


FIGURE 59.—Section across the valley of the Gila River at Gillespie Dam, Ariz. After C. P. Ross. Ql, Quaternary lava; Tl, Tertiary lava; Ts, Tertiary sandstone; Agr, granite

The rocks underlying this region are granite and schist of pre-Cambrian age which present a rolling surface under the volcanic deposits.

West of Crag the railroad reaches outcrops of lavas and other volcanic rocks which are extensively displayed in the pass at the divide near Harqua and in many surrounding ridges.

In this desolate region the desert flora is well represented by various cacti, including scattered sahuaros, many covilleas, and much paloverde and mesquite, the last named being most conspicuous along the dry washes. The volcanic succession has great thickness in the prominent flat-topped Woolsey Peak,[57] which is conspicuous to the south at intervals from Crag to Gillespie. Cimmerian Peak is the highest point

[56] According to C. P. Ross the rocks in Saddle Mountain consist of fine-grained reddish latites, hornblendic felsites, and gray vesicular basalts. There are also considerable thicknesses of fragmental rocks, mostly volcanic agglomerates and breccias. Some of the rounded forms and hollows appear to be due to a disposition to curved exfoliation and not the result of solution or erosion. The Palo Verde Hills, which lie just east of Saddle Mountain, consist mostly of the younger basalt, but a butte hear the Palo Verde mine is a fine-grained hornblende granite.

[57] Named from King Woolsey, the pioneer settler on the Gila River who engineered the "Pinole treaty," in which many Indians, invited to come unarmed to a feast and council, were treacherously set upon and slaughtered by their host and his friends.

on a prominent serrated ridge which extends to July 4 Butte and probably marks a great igneous dike. The old mail road from Phoenix to Yuma crossed these mountains in a pass between Cimmerian and Woolsey Peaks and, descending Woolsey Arroyo, reached the bank of the Gila River at Agua Caliente (ca-liane'tay). It passed Woolsey Well, formerly a favorite camping place, about 3 miles west of Woolsey Peak, where some interesting geologic features are exposed. The basement lavas are overlain by conglomerate and sandstone of Tertiary age, tilted gently to the west. These rocks are capped by a sheet of basalt and intersected by several dikes and sills of basalt. Some of the boulders in the conglomerate are from 1 to 3 feet in diameter.

About 2 miles northwest of Gillespie is the Old Dixie mine, where shale and andesitic agglomerate are cut by quartz monzonite porphyry that was probably intruded in Tertiary time.

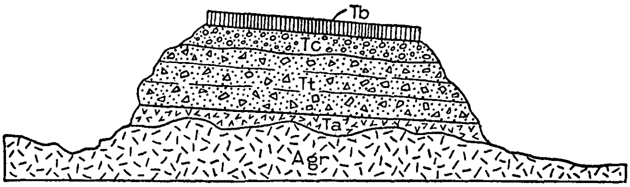


FIGURE 60.—Section in Yellow Medicine Butte and adjoining mountains, Arizona. Tb, basalt; Tc, conglomerate; Tt, light tuff; Ta, andesite, etc.; Agr, granite

On approaching Harqua siding the railroad passes through cuts of granite in a small exposure in the midst of the volcanic succession.

Harqua.
Elevation 1,078 feet.
New Orleans 1,677 miles.

From the divide at Harqua siding there is a rapid descent into the wide alluvial flat of Quail Spring Wash. To the north from a point near Saddle siding there is an excellent view of Yellow Medicine Butte, which consists of a high southward-sloping cuesta of basalt capping a thick mass of tuffs. A fault traverses this cuesta, breaking it into two portions. This succession and the basement of granite on which it lies is general throughout the region, notably in the Montezuma Cuesta and its companion to the south; in Columbus Peak, where the dip is 20°; and in the Agua Caliente Mountains. The relations are shown in Figure 60.

Beyond Papago siding a gap leads between basalt-capped mesas. Passing Montezuma and Camel sidings the lowlands on the north side of the Gila River are entered. To the north is a fine view of a feature known as Montezuma Face, which, as shown in Plate 32, *A*, presents a remarkably natural face profile looking upward.

At Hyder the railroad passes north of the basalt-capped mesas known as the Agua Caliente Mountains, the slopes of which are covered with talus. A big dike in the hill just north of the railroad extends southward under the northernmost of these mesas. At the south end of these mesas are the warm springs at Agua Caliente (Spanish for hot water), where a health resort has been established to utilize the water. The priest-explorer Sedelmaier visited them in 1748, and Garcés and Font mention them in their diaries of the Anza expedition of 1775. For a long time Agua Caliente was a station on the old stage road that crossed the mountains near Woolsey Well.

Hyder.
Elevation 536 feet.
Population 20.*
New Orleans 1,704 miles.

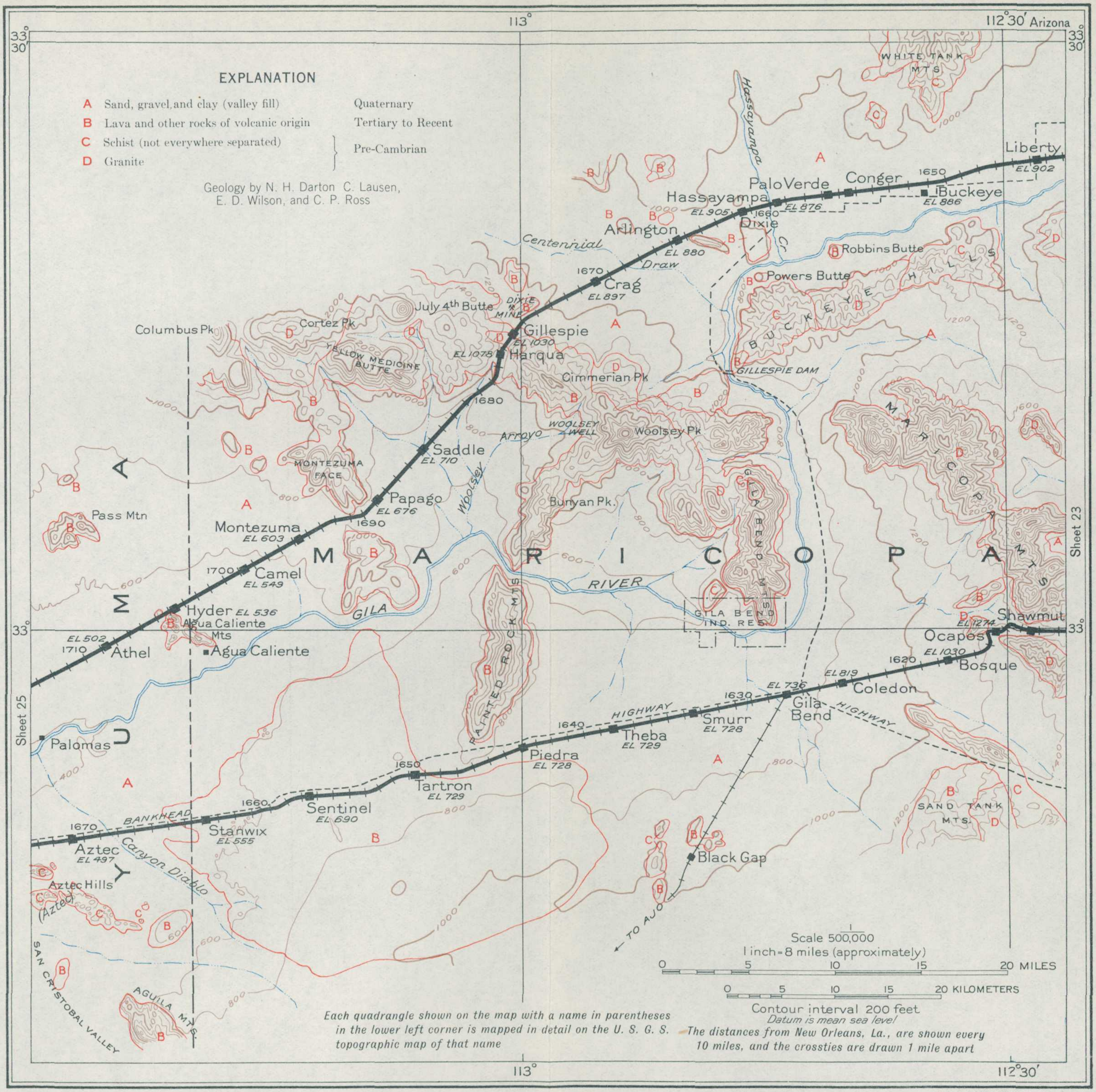
Sahuaros occur on the plains and hillsides nearly to Athel siding, together with widely spaced bushes, mainly *Covillea.*

At Athel siding the sharp peaks of Pass Mountain, a group of volcanic buttes 8 miles to the north, are seen, and northwest of Athel and north from Horn to Kofa (turn to sheet 25) the Palomas Mountains are conspicuous. These mountains consist of a cap of basalt on a thick deposit of volcanic tuff and ash, which lies on and against granite that constitutes the western range of the mountains.

From Horn to Growler siding and beyond the desert plain is covered with low sand dunes. In this vicinity the railroad approaches the north bank of the Gila River in the midst of a wide desert plain into which the river has cut a broad inner trench about 50 feet deep. The stream meanders widely in this alluvial flat, and for many miles the south bank of the trench presents a long line of northward-facing cliffs of sand, loam, and gravel. The region is arid, with an annual rainfall of less than 5 inches in the lowlands, and consequently vegetation is very sparse. Yet there are scattered cattle ranches and goat or sheep outfits, and in seasons of average rainfall and where drinking water is provided the stock business has prospered. The river is one good source of supply, and in the adjoining region water is obtained from widely scattered wells, mostly of considerable depth and yielding only a moderate volume. In the mountains of the general region there has been a small amount of mining or prospecting, but the results do not appear to have been satisfactory.

Horn.
Elevation 468 feet.
Population 25.*
New Orleans 1,714 miles.

At Burger siding Texas Hill is visible to the south, evidently a feeder for a small flow of basalt. The Anza-Garcés expedition, which followed the north bank of the river for a few miles, camped at the foot of this hill on the night of November 16, 1775. Signal Butte, northwest of Growler, is of similar character. In this vicinity the Mohawk Mountains (p. 232) are a prominent feature to the south. About 30 miles to the north the steep western front of the Kofa Mountains is conspicuous. At its foot were the King of Arizona,



Topography by N. H. Darton, C. Lausen, and E. D. Wilson

WILLIAMS & HEINTZ CO. WASH., D. C.

North Star, and other gold mines, which at one time, it is claimed, yielded nearly $5,000,000 in gold and silver, much of it from very high grade ore, some of which assayed as high as $20,000 a ton (Yearbook of Arizona, 1930). The ore bodies were in veins in volcanic rocks (andesites) of Tertiary age.

North from Tyson siding the peaks of the south end of the Castle Dome Mountains are conspicuous. They consist of a central core of schist, heavily flanked by lavas of Tertiary age. Far to the north may be seen the culminating summit, Castle Dome Peak, which is a prominent landmark in a region of wide extent. This peak was called Bauquiburi by the Indians and was often referred to in the narratives of early travel as the Cabeza del Gigante (ca-bay′sa del he-gahn′tay, Spanish for head of the giant). There are mines near its base on the west slope of the range.

Roll.

Elevation 265 feet.
Population 40.*
New Orleans 1,745 miles.

South of Roll the prominent, sharp Baker Peaks are in view south of the Gila River, and beyond them the rugged crest of the Copper Mountains. Roll is a small settlement sustained by irrigation, using water pumped from sand and gravel holding underflow from the river. To the west are the prominent Muggins Mountains, and to the north the west side of the Castle Dome Mountains is conspicuous. The wide river terraces to the west are deeply trenched by arroyos.

Just west of Roll the railroad line bends southwestward toward the Gila River, which is crossed at the north end of Antelope Hill, as shown in Plate 33, *B*. This hill is composed of light-colored arkose and arkosic sandstone supposed to be of Tertiary age, of which about 500 feet is exposed, dipping to the south at a low angle. Other exposures of the same rock constitute the north end of the Mohawk Mountains, as shown in Plate 32, *B*, the two knobs a mile southwest of Ming siding, and the Baker Peaks, southeast of Ming. The rock is quarried extensively at two places near the river.

After crossing the Gila River the railroad turns to the south-southwest and, rising onto the wide upland terrace, here 50 feet above the river flat, joins the old main line at Wellton.

Wellton.

Elevation 258 feet.
Population 80.*
New Orleans 1,756 miles.

Wellton is a local trading settlement for the cattle and irrigation industry and a headquarters for mining interests of the surrounding country. There is considerable irrigation near by and for a few miles west from wells and from ditches taken out of the Gila River. The village is situated on a wide desert plain 2 or 3 miles south of the river. High mountains are visible on all sides. To the north are the Muggins Mountains, an irregular series of high ridges of Tertiary volcanic rocks heavily flanked to the east and south by conglomerates and other strata of later Tertiary age. Farther north are the high pinnacles and ridges of the Castle Dome Mountains. To the west are the lofty Gila Mountains, consisting of granite and schist; to the south are many low ridges of schist, making the Wellton Hills; and to the southeast the Baker Peaks and the Copper Mountains, referred to above. To the north is an irrigated district of considerable size which is closely approached by the railroad near Adonde siding.

OLD MAIN LINE, PICACHO TO WELLTON, ARIZ.

Until 1928 the trains of the Southern Pacific lines continued northwestward from Picacho to Wellton via Maricopa, where there is a branch to Phoenix. Now most passenger trains pass over a new line northward from Picacho to Phoenix and thence down the north side of the Gila Valley to join the old line at Wellton, as just described. The old line from Picacho to Wellton is described below.

Eloy.

Elevation 1,566 feet.
Population 13.
New Orleans 1,549 miles.

Near Eloy siding (see sheet 23, p. 206) an irrigation district which extends to Casa Grande is entered. Cotton and alfalfa are the principal crops, together with melons, figs, and a fine variety of head lettuce for which the soil and climate seem particularly suitable. The lettuce is ready for shipment in November, before it is available from competing districts. The water is brought by ditches from the Gila River near Florence, and considerable water is also pumped from wells in the valley fill using electricity as an economical source of power

Arizola.

Elevation 1,435 feet.
Population 30.*
New Orleans 1,559 miles.

About midway between Toltec siding and Casa Grande the railroad passes north of the Casa Grande Mountains, a group of rugged peaks of pre-Cambrian schist. Three miles to the northeast are the Three Peaks, which consist of granite. About 15 miles southwest of Toltec are the conspicuous Sawtooth Mountains, which consist of lavas of Tertiary age.

Casa Grande.

Elevation 1,398 feet.
Population 1,351.
New Orleans 1,564 miles.

Casa Grande is on a broad, smooth plain of sand and loam (valley fill), in which the slope of the land is scarcely perceptible. The mean annual rainfall is about 6½ inches. About 18 miles northeast of Casa Grande station are the ruins of the prehistoric houses of Casa Grande, which are near the railroad on the main line from Picacho to Phoenix. (See p. 197.) Nine miles south of Casa Grande is the Papago Indian village of Chiu-Chiuschu (population 349), where there is a school and a pumping plant to obtain water for irrigation. Many detached mountains and rocky buttes are visible in all directions from Casa Grande and vicinity.[58]

[58]About 15 miles to the south are the Slate Mountains, which consist largely of schist overlain to the west by an interesting succession of Paleozoic rocks comprising Bolsa quartzite and Abrigo limestone (Cambrian) and Martin

The low range of buttes rising abruptly from the plain a few miles north of Casa Grande and extending thence westward are the Sacaton Mountains, which consist of massive light-colored granite (mica diorite). There is a small knob of this material 3 miles northeast of Nuñez siding, and it appears in many of the ranges to the north and west. It is an intrusive rock which has been forced up in molten condition through the old schist in pre-Cambrian time.

At the small station of Maricopa is the branch line to which formerly passengers for Phoenix were transferred. Now, however, as explained on page 224, most of the trains go directly to Phoenix from Picacho. Maricopa is situated on a broad desert plain not far from the Santa Rosa Wash and the Santa Cruz River, both of which are generally dry. In this vicinity there is a small amount of irrigation by water pumped from wells. Many mountains rise abruptly from this plain, the Sierra Estrella to the north and the Palo Verde Mountains to the west, which are continued southward by various ridges of schist and granite to the high Table Top Mountains, 25 miles south of Maricopa. This range, which does not appear distant, culminates in a flat-topped peak that has an elevation of nearly 4,000 feet and consists of a cap of basalt presenting steep cliffs on all sides. Some distance northwest is the steep conical summit known as Antelope Peak, composed of a sheet of lava dipping at a steep angle. Below these lavas are granites and schists rising to an irregular plane which in Tertiary time was a general surface on which the lavas were poured out. Subsequent uplift, tilting, and erosion have left the remnants of the lava flows perched high above the general desert level, a feature which is general in a large part of southwestern Arizona.

Maricopa.

Elevation 1,175 feet.
Population 30.*
New Orleans 1,585 miles.

West of Maricopa the railroad ascends slightly to reach at Enid siding the wide pass between the Sierra Estrella on the north and the Palo Verde Mountains on the south. The Sierra Estrella is a very prominent range which extends 25 miles north to the mouth of the Salt River, with an average width of 3 miles and a maximum height of about 3,000 feet above the plain. Montezumas Head, at the south end, has an elevation of 2,406 feet. The northeastern front of the range is very steep and rugged up to about 2,000 feet, where some of the canyons open into valleys. The range consists mainly of schist, but this rock is invaded by large intrusive masses of granite, one of which at the south end extends nearly to the railroad. A

(Devonian) and Carboniferous limestones. The Abrigo beds at this place consist of slabby brown sandstones, in part glauconitic (greensand), with brown and gray shales. They contain worm markings and lingulas of Cambrian age. The overlying limestones (Martin) carry abundant Upper Devonian fossils that indicate an extension of the sea waters of Paleozoic time over much of western Arizona.

granite aplite intrusion occupies an area of 5 or 6 square miles between North Peak and the Webb mine. Dikes of coarse granite and diabase also occur.

The Palo Verde Mountains, south of the gap at Enid, consist of schist and are part of a line of ranges extending south through the Vekol[59] and Cimarron Mountains. They are about 800 feet high, deeply canyoned, and possibly bounded by a fault at their steep northeast end. In the pass between the Palo Verde and Table Top Mountains, the range next south, there are ledges of Tertiary arkosic conglomerate interbedded with basalt flows, the lowest of which rests on granite. The beds dip 14° SW. Some of the boulders, which are granite, are 6 to 8 feet in diameter.

The wide plain of the Estrella Desert is crossed west of Enid to reach a low pass through the northern part of the Maricopa Mountains. This pass is drained by Waterman Draw, and wells in the valley fill near this draw have obtained sufficient water for cattle, which find sparse pasturage in the valley and adjacent slopes. The divide is just east of Estrella siding (elevation 1,523 feet), where there is a wide gap floored with gravel and sand between high granite ridges. Wells drilled in the valley fill at Mobile siding (452 feet deep), at Ocapos siding (541 feet deep), and at Estrella found water which rose high in the borings but was insufficient in quantity for locomotive use. It was through this pass that Padre Garcés traveled in 1775 on the way to Yuma, and he called it Puerto de los Cocomaricopas. (See p. 194.)

Beyond the Estrella divide (see sheet 24) the railroad descends to Ocapos siding in a wide valley with walls of granite. The Maricopa Mountains consist mostly of this rock, with a minor amount of schist. The east slope of this range north of Estrella has at its foot a moderately wide pediment or slope of nearly bare rock, trenched but slightly by streams. At one place this pediment is surmounted by a hill of gravel capped by a remnant of a basalt sheet tilted to the east, which indicates uplift since the extrusion of the lava. On the west side of the mountains and in the pass there is a thick mantle of valley fill.

[59] South of the Table Top Mountains, about 45 miles south of Maricopa, are the Vekol Mountains, which are of great geologic interest, for they contain not only a succession of Paleozoic limestones including some strata of Permian age but an outlying mass of formations of the Apache group (Algonkian) lying on pre-Cambrian schist and closely resembling the succession in central Arizona. Some hard red shale at this place resembles the Pioneer shale, and it is capped by a conglomerate like the Barnes. An overlying quartzite like the Dripping Spring quartzite is penetrated by thick sills of dark-green diabase. Next above are rusty sandy shales grading up into thin-bedded limestone containing Upper Cambrian fossils, undoubtedly the Abrigo limestone. The higher limestone in an adjoining ridge carries a remarkable fauna of minute fossils, pelecypods, scaphopods, and gastropods, of about 25 species of late Carboniferous age.

South of Bosque siding are the Sand Tank Mountains,[60] which consist of a long, high ridge of schist and granite and a high, wide tabular mesa of volcanic rocks in a succession nearly 2,000 feet thick. This region was a center of great volcanic activity in Tertiary time, when widespread sheets of lava were poured out over the land. These have since been uplifted, tilted, faulted, and greatly eroded.

Gila Bend.

Elevation 738 feet.
Population 800.*
New Orleans 1,627 miles.

Gila Bend is a town sustained by cattle, irrigation, and mining interests and is the headquarters for the Gila Bend Indian Reservation, near by, where there is a colony of about 224 Papago Indians. The climate is very dry, with a mean annual precipitation of only 6 inches. A branch railroad connects Gila Bend with Ajo (ah'ho, Spanish for garlic), 30 miles to the southwest, a copper-mining town which has a population of 3,003. Copper has been mined at Ajo since 1855, mainly from the Cornelia mine. Most of the ore carries less than 1½ per cent of copper, but it is easily worked and occurs in large amount. The ores are mainly disseminated in monzonite porphyry and a small amount is disseminated in veins in rhyolite and tuff, into which the porphyry is intruded. It is estimated that 40,000,000 tons of ore is available. There are also dikes of diorite and later porphyry, all presumably of Tertiary age. In 1929 a total of 3,582,000 tons of ore containing from 1 to 1¼ per cent of copper was treated.

South of Gila Bend are the Sauceda Mountains, a high range consisting mainly of a thick succession of Tertiary volcanic rocks of which the latest member is basalt. Hat Mountain, a prominent landmark 25 miles south of Gila Bend, has a cap of this basalt, a remnant of a lava flow of Tertiary time.

Gila Bend is in the broad valley of the Gila River, which in making its huge bend southward around the Gila Bend Mountains approaches within 4 miles of the town. In this region the river is a wide watercourse which ordinarily carries only a small flow. It was in this vicinity that Padre Kino found a prosperous Opa (Maricopa) Indian ranchería in 1699, and it was visited in 1774 by Anza and Garcés, who called it the Pueblo de los Santos Apóstoles San Simón y Judas. There were other rancherías along the river at which the Indians were raising two crops of grain a year by irrigation with river water. This was the farthest east that the Maricopa Indians had advanced up the river, but they have since moved to the region southeast of Phoenix.

[60] At the Sand Tanks, a watering place in these mountains 23 miles southeast of Gila Bend, the water is found in holes eroded in a conglomerate of Tertiary age which dips 20° N. This rock lies on granite gneiss and consists mostly of tuffs and sandy tuffs containing pebbles of granite, schist, and volcanic rocks of various kinds. The schists in the central ridge are mostly chloritic, and there are many transitions from schist to gneiss. Fine-grained biotite granite and phyllite also occur.

The valley fill here is thick, for borings 1,530 to 1,730 feet deep, for water, appear not to have reached bedrock, unless "hard beds" in the lower 550 feet are Tertiary or Cretaceous. In the surrounding region there is a succession of older beds of gravel and sand [61] which are mostly tilted and in places faulted. They are overlapped unconformably by the later sand and gravel that floor the valley. There are excellent exposures of these relations on the slopes of the Gila Bend Mountains near Woolsey Well, 15 miles northwest of Gila Bend, and farther west at the north end of the Gila Bend Mountains west of Dome.

As the Gila Valley below Mesa is filled with a thick mass of alluvium underlain in part by sandstone of Tertiary age, it is evident that the region was 1,000 feet or more higher when the valley was being excavated than it is now, and it has sunk to its present level as the younger formations were deposited. Possibly this loading was the cause of the sinking, but more likely it was due to some widespread crustal movement. A notable feature revealed by the logs of deep borings in the valley is a deposit of clay of wide extent, with a maximum thickness of 860 feet at Gila Bend. This clay must have been deposited in quiet waters, such as those of a lake or estuary that continued for a long period of time. The deposition of clay was followed by the accumulation of coarser material spread by streams, and since that time terraces higher than the present bottom lands have been developed. In places these later deposits were flooded by lavas, through which the present river trench has been excavated nearly 100 feet. From the historical record the Gila River channel has changed materially in a century or less. When it was originally discovered there was a well-defined channel with hard banks sustaining cottonwoods and other trees and plants. The current was swift and deep in places, so that the stream could be navigated by flat boats of moderate size, and it contained sufficient fish to be relied upon as food for many Indians. It was reported also that the water was clear and sea-green, very different from the present muddy stream. Now the Gila River is depositing sediment in its lower part, and its braided course follows many narrow sand-clogged channels. Possibly these changes may be due partly to diverting and damming the water and to an increase of silt caused by the removal of forest and increased grazing in the higher region.

Irrigation has been practiced in this region for a very long time, for old Indian ditches are found near the Painted Rock Mountains below Gila Bend and at other places along the river flats. Irrigation was again started in a small way by settlers who came soon after the

[61] These older beds are in general correlated with the Temple Bar conglomerate of Lee and the Gila conglomerate of Gilbert. In places they include lava flows (basalt) which are tilted and faulted.

bimonthly stage line between San Antonio and San Diego was established in 1857. The area under cultivation was small, but it was increased somewhat in the early seventies, and continued intermittently until 1905, when a heavy flood destroyed most of the canals. Some of these canals have since been restored and new ones developed, but the principal enterprise now in operation is the utilization of water held by the Gillespie Dam, 20 miles north of Gila Bend. (See p. 219.)

The lower Gila River Valley figures prominently in the chronicles of many of the early explorers of Pimería Alta. When Kino explored this valley in 1699 and 1700 and Garcés in 1771 and later, they found many Indian rancherías and some irrigation, but the adjoining region was so inhospitable that it supported only a meager population. The Pimas and some Papagos dwelt on the banks of the Gila near the mouth of the Salt River, and these streams furnished water for considerable irrigation. The Maricopas, who were of Yuman stock, moved gradually up the Gila Valley, pausing at Gila Bend in Garcés' time and finally reaching the Phoenix region, where many now reside with the Pimas. The Yavapais or Apache-Mojaves lived in part in the region between the Colorado and Gila Rivers. In early days they were friendly to the whites, but after suffering various injustices they went on the warpath in 1868 and were troublesome for several years. Oatman Flat, on the Gila River a few miles northwest of Gila Bend, was the scene of an Apache attack in 1851, in which an emigrant named Oatman and his family were killed, except a young son who escaped and two daughters who were carried off. The girls were sold as slaves to some Mojave Indians, and one who survived was ransomed seven years later. This case attracted much attention and was the subject of a narrative [62] that had a large circulation.

North and northwest of Gila Bend the Gila River resumes its westerly course. The steep Gila Bend Mountains, which are in sight from the railroad for many miles, consist largely of granite with a thick succession of Tertiary volcanic rocks overlapping it on the west. These younger rocks are thick in Woolsey Peak in the center of the range, which is made up of light-colored lavas and some fragmental volcanic rocks. On the western extension of the range these rocks are capped by a thick sheet of dark-colored basalt, constituting prominent mesas. One of the highest and most extensive of these mesas is called Yellow Medicine Butte. About 14 miles north of Piedra station a large basalt-covered cuesta extends with a long slope to the Gila River, which swings north in order to pass between it and the north end of the Painted Rock Mountains. The railroad, on the other hand, passes near the south end of these mountains, near Piedra and Tartron sidings. The Painted Rock Mountains consist of lavas of Tertiary

[62] Stratton, R. B., Captivity of the Oatman girls and an account of the massacre of the Oatman family in 1851, San Francisco, 1857; New York, 1858.

age, capped in part by basalt, tilted, faulted, and considerably eroded. The name is derived from Indian pictographs on bluffs near the river.

On approaching Tartron siding the railroad climbs a few feet to the nearly level surface of a broad sheet of lava of relatively recent age which extends about 17 miles, to a point beyond Stanwix siding. This flow, which is wide to the north and south, doubtless came from several vents. The remains of one crater, probably a source of a considerable part of the lava, is a knob of moderate height 1½ miles northwest of Tartron siding. A long ridge southeast of Sentinel siding probably marks another outlet. The lava, which is thin near its edges, lies on gravel and sand and is of recent origin compared with the lavas constituting the summits of the high adjoining ridges that have been uplifted and in large part widely removed and cut back by erosion. This recent lava undoubtedly dammed the Gila River for a while, but the stream has since cut a trench about 100 feet deep across its northern portion. In places the younger lava abuts against slopes of the older volcanic rocks, and it occupies valleys developed since the older rocks were flexed and faulted, a condition indicating a long-time interval. Several wells at Sentinel siding pass through 60 to 100 feet of this lava and obtain a good water supply from the underlying sands, which were penetrated to a depth of 1,129 feet.

Tartron.

Elevation 729 feet.
New Orleans 1,650 miles.

Sentinel.

Elevation 690 feet.
New Orleans 1,656 miles.

From the Sentinel Plain there are extensive vistas across the desert to the lofty Growler Mountains, far to the south; to the commanding and nearer Aguila Mountain (ah′ghee-la), to the southwest, culminating in a high northward-sloping plateau of lava; and to the Aztec Hills, to the west. Back to the southeast Hat Mountain (p. 227) is conspicuous. To the north are many ranges, mostly of volcanic rocks, which lie beyond the Gila Valley.

In this part of Arizona the railroad crosses wide desert plains, mostly covered by creosote bush (*Covillea*). Very little of this land can be reclaimed by irrigation, on account of the scanty water supply. The question of water is the most important consideration in these desert regions, not only for domestic use and for locomotives, but for the cattle industry, which can not exist without it. Tanks created by damming draws hold some of the rainfall, but the loss by evaporation is very great in this region, the depletion averaging more than 6 feet a year. The Gila River is the only stream that runs continuously, and the few springs that exist are widely scattered. A small amount of water is held in natural basins in the rocks, known locally as tinajas (tee-nah′has, Spanish for large earthen jars). Wells find water in the gravel and sand of the desert, in crevices in rocks of the mountains, and under some of the lava flows, but the amount is generally small. The scant rainfall wets the soil and in large part evaporates, but some of it passes underground into the coarser materials, which occur mostly along the sides of the valleys. The water is available in some places in the valleys, but ordinarily it is only sufficient for domestic use or for a few cattle. Along the river flats there is a ground-water plane sustained by the streams and extending laterally for some distance; this is the source of supply for many wells, some of which in the lower Gila Valley yield water for irrigation. In the lower part of the Salt River Valley also the underflow is extensive and in much of the area of ample volume.

The desert landscape has many peculiarities. At first sight its wide gray plains and bare mountain slopes seem forbidding and monotonous. However, they have a certain grandeur and present attractive variations in light and shade during different portions of the day and from day to day. Some of the sunsets are particularly beautiful. Under the direct rays of the midsummer sun the heat is intense, but ordinarily the low humidity keeps the skin comfortable, and there is much less suffering from the heat than in a moist region at much lower temperature. Mirage is frequent, especially the sort due to a film of vibrating hot air near the ground, which gives the illusion of distant lakes. In the higher mountains precipitation is greater than in the valleys, the temperatures are lower, and occasionally there is snow. Everywhere the rains are followed by rapid growth of many flowers. The desert region of the southwest corner of the United States is a part of the Sonoran Desert, which extends north from the State of Sonora in Mexico and is very much of a unit in climate, vegetation, and general aspect. Rainfall, which ranges from 3 to 6 inches a year in the region west of Phoenix, comes mostly in widely separated heavy downpours in narrow streaks, many of them "cloudbursts," which give rise to local sudden freshets of great volume. One of these in 1930 washed out a large part of Wellton. Some floods are not confined to a channel but extend widely over the valley floor.

Sand storms occur occasionally on the deserts of New Mexico, Arizona, and southern California, but most popular accounts of them are greatly exaggerated. The following description (by C. P. Ross) will give some idea of a typical sandstorm. It followed showers in the mountains and came from the southeast, where at frequent intervals before, during, and after the blow there were sharp claps of thunder. At first there came bodies of flying sand in long, thin pillars reaching far upward and resembling waterspouts in shape and appearance but moving with much greater speed. These were followed by billowing clouds of sand, which, however, did not transport much material, and then came the main blow in dense waves and carrying a large percentage of fine sand. Where these waves struck the mountains they were shattered, and the sand was whirled high on the foothills, much like waves of water driven by a hurricane. In 10 to 15 minutes from the coming of the first sand the storm diminished, especially as to the amount of sand. During the height of such a storm it is difficult to travel, mostly because the sand is blinding. It also penetrates the clothing and fills the hair and every wrinkle of the skin not well protected, so that it is somewhat uncomfortable, but there is almost no cutting of the skin. Sand storms as severe as this are rare.

Aztec.

Elevation 497 feet.
Population 40.*
New Orleans 1,671 miles.

A 710-foot well at Aztec yields an excellent water supply. Below 145 feet of sand it penetrated 455 feet of red clay, an extension of the thick bed penetrated by deep borings at Gila Bend. Three miles due south of Aztec and conspicuous from the railroad is a white quartz knob that is on a spur of the Aztec Hills, which consist mostly of schist and granite. At the west end of these hills, 4 miles west of Aztec and about a mile south of the railroad, there is a quarry in schistose granite, which is crushed for use on the roads. (See sheet 25.)

Stoval.

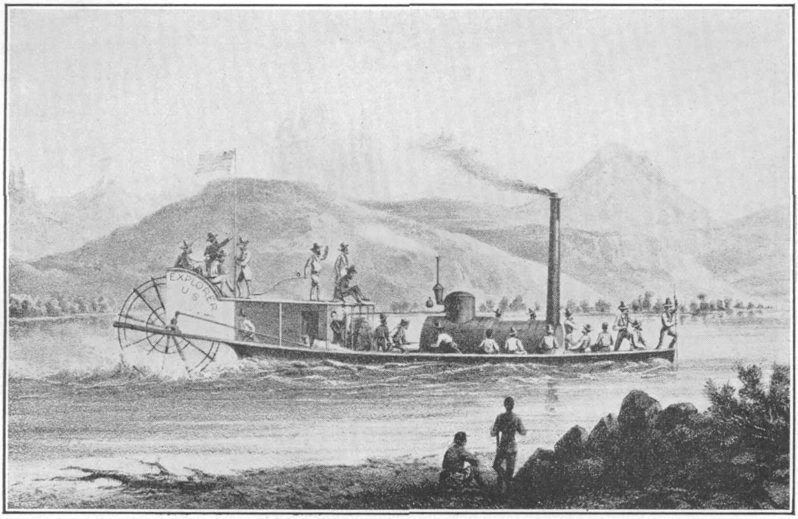
Elevation 378 feet.
Population 30.*
New Orleans 1,682 miles.

Texas Hill, 6 miles northwest of Stoval, is a small butte on the north bank of the Gila River consisting of basalt, probably part of a small flow. Near it Garcés camped in 1775 in company with Anza's expedition to California. The old settlement of San Cristóbal, of which the station name is an abbreviation, was near this hill. Saints' names were sprinkled over the country by all the early explorers, and most of them do not indicate the presence of a mission. West from the Aztec Hills is a wide desert known as the San Cristobal Valley extending to the foot of the Mohawk Mountains. A well sunk 700 feet in the valley fill at a point about 4 miles south of Stoval found considerable water, which it was hoped could be used for irrigation. This valley, like many others that lead to the Gila River, is not trenched by its stream except where it approaches the river, north of the railroad, but its bottom is a broad adobe flat.

Mohawk.

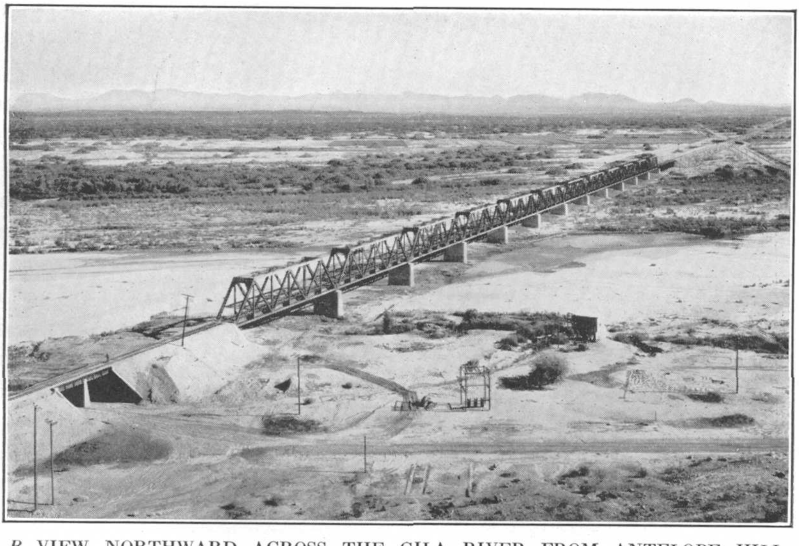
Elevation 545 feet.
New Orleans 1,690 miles.

The northern part of the Mohawk Mountains is crossed by the railroad in a moderately high, rocky gap at Mohawk. These mountains are very rugged and bare and consist largely of pre-Cambrian schist penetrated by granite. Contacts of these two rocks are visible near the railroad. At the north end of the mountains the schist is flanked by a thick succession of conglomerate, sandstone, and shale of probable Tertiary age, dipping steeply to the southwest. The granular schist a short distance northwest of Mohawk, which is quarried for road material, contains veins of barite that have been mined in small amount. Five miles south of the station, on the east side of the mountains, is the old Norton or Red Cross mine, which produced a small amount of rich silver ore many years ago. The rock pediment on the west foot of the mountains is heavily flanked by loose sand, which has been blown by the



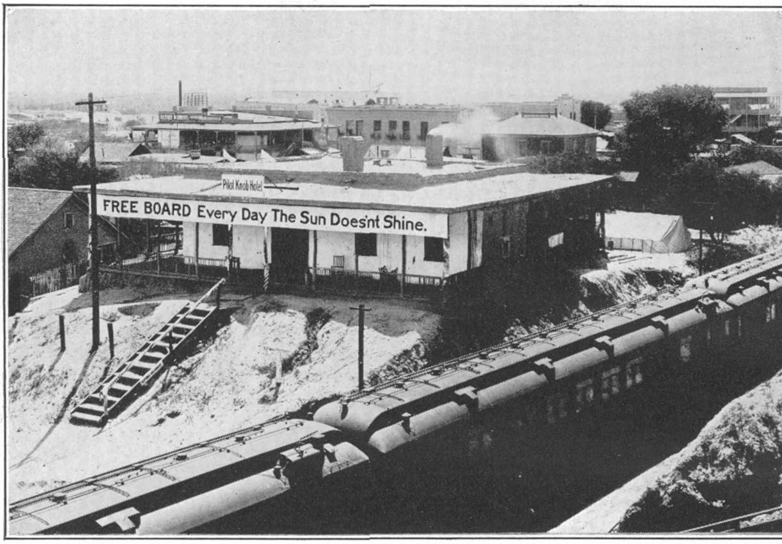
A. THE "EXPLORER"

A drawing of the steamboat used by the Ives expedition up the Colorado River.

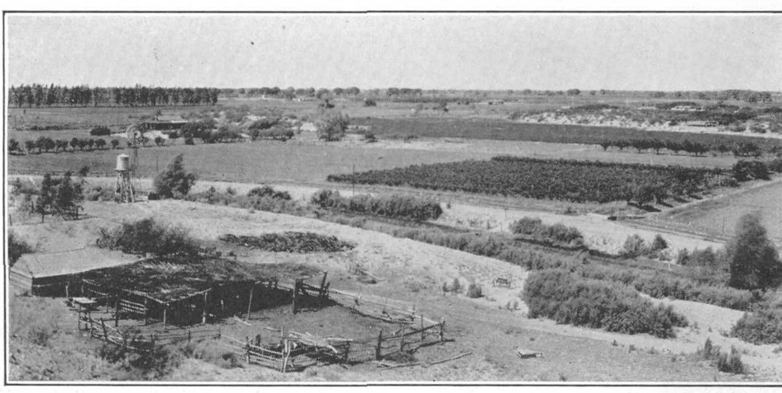


B. VIEW NORTHWARD ACROSS THE GILA RIVER FROM ANTELOPE HILL, BETWEEN WELLTON AND ROLLS, ARIZ.

Castle Dome Mountains in distance; irrigated fields in middle ground.



A. PART OF YUMA, ARIZ. (1923)
The income of this hotel was rarely interrupted.



B. IRRIGATED DISTRICT ON THE LOWER LANDS NEAR YUMA wind and accumulated at the foot of the slope. Farther north, near the railroad, this pediment is deeply trenched by small arroyos. At the north end of the Mohawk Mountains is the Gila River; at this place Garcés in 1775 crossed to the south side of the river. The Mohawk Mountains were named Cerro de San Pascual by Anza on his expedition of 1774; he camped at their north end the following year.

West of the Mohawk Mountains is the wide desert plain of Mohawk Valley, which extends west for about 15 miles to a line of ridges consisting of the lava-capped Cabeza Prieta Mountains (cah-bay'sa pre-ay'ta, Spanish for black head), to the south; the Copper Mountains, a conspicuous rugged range of granite southwest of Colfred siding; and the Baker Peaks, a short distance south of Tacna siding. The prominent Baker Peaks, named for Charles Baker, who in early days ran a ferry across the Colorado River at Yuma, consist of tilted sandstones presumably of Tertiary age.[63] South of the Baker Peaks are ridges of conglomerate, also of Tertiary age, extending to the flank of the Copper Mountains. Far to the north are the fantastic summits of the Castle Dome Mountains. Closer at hand to the northeast from Colfred siding is Signal Butte, rising prominently above the desert plain a scant 5 miles beyond the Gila River. It is a small mass of basalt probably marking the center or outlet of a minor lava extrusion.

A mile north of Tacna siding and extending for a mile to the bank of the Gila River is Antelope Hill, about 600 feet high. It consists of grayish arkose composed largely of granite débris and probably of Tertiary age. The dip is to the south at a low angle, and about 500 feet of beds are exposed. There are also small exposures of this rock in smaller buttes just north of the railroad 2 miles farther west, in which the dip is 15° SW., and another small exposure northeast of Antelope Hill. The material has been quarried extensively, mainly for road metal.

At Wellton the old main line of the railroad is joined by the new line from Picacho by way of Phoenix. (See p. 223.)

[63] These rocks are well exposed at Baker Tanks, 5 miles south of Tacna, where the conglomerate dips 65° SW. The beds are mostly an aggregate of quartz and feldspar grains, but some beds are a coarse conglomerate with many pebbles and boulders from 3 inches to 3 feet in diameter. The material is so similar to gravel deposited by present streams on the slope of Baker Peaks as to indicate that it was derived from the same rocks under conditions similar to those which now exist.

WELLTON TO YUMA, ARIZ.

Wellton.

Elevation 258 feet.
Population 80.*
New Orleans 1,713 miles (via Phoenix, 1,756 miles).

In the vicinity of Wellton small areas are irrigated by water pumped from wells that draw their supply from the ground water of the Gila Valley. A 1,120-foot boring at Wellton passed through 750 feet of sand and clay, regarded as valley fill, and 370 feet of harder strata, including sandstone, which probably are Tertiary. About 6 miles south of the station are the Wellton Hills, a group of small knobs and ridges consisting of mica schist with minor amounts of granite, all of pre-Cambrian age. They are in the midst of the Lechuguilla Desert (lay-choo-ghee'yah), a broad, flat valley extending south into Mexico, the international boundary being about 40 miles south of Wellton. Near the international boundary are the Tinajas Altas, rock tanks containing water. They were a famous stopping place on the Camino del Diablo (highway of the devil), a cross-country thoroughfare much used in early days and so called because of the difficulties of travel and the lack of water, which caused many deaths. This road crossed the Gila Mountains 18 miles south of Wellton and passed near the Fortuna mine on the way to Yuma, a hard journey across the loose sands of the Yuma Desert. The Gila Valley route followed by Garcés encountered west of Wellton an area subject to inundation from the river. Much later stage-coach travel stopped at a place called "Mission Station," near Adonde (ah-dohn'day), a few miles west of Wellton.

West from Wellton the railroad passes through the sidings of Adonde and Ligurta and, following the south bank of the Gila River, enters the wide gap by which that stream passes around the north end of the Gila Mountains, a very characteristic desert range that consists of granite and schist of pre-Cambrian age and that doubtless is, in part at least, a fault block. A short distance north of Ligurta fossil bones found in the alluvial deposits of the river indicate the presence of not only an ancient variety of deer but also of the native horse, which became extinct in this country thousands of years before horses were introduced by the Spaniards, a few centuries ago. To the north is a fine view of Klotho's Temple, in the Muggins Mountains, which consists of volcanic rocks. At Granite siding the railroad reaches the rocks of the mountain slope, and granite is well exposed in cuts and a quarry. From the quarry a large amount of crushed rock is produced for railroad ballast on many miles of the Southern Pacific lines. A thin mass of marble exposed in the north end of the Gila Mountains has been quarried to some extent for building. Portions of it are nearly pure calcium carbonate. The relations of the rocks in this region are shown in Figure 61. The granite is cut by many dikes of dark intrusive rocks and traversed by veins of light-colored pegmatite. To the north is the Gila River, now so well controlled by dams that it no longer is subject to the devastating floods which it formerly carried.

The long deflection of the railroad in following the river around the north end of the Gila Mountains is avoided by the highway, which goes through a high pass nearly due west of Wellton.

Dome.

Elevation 190 feet.
Population 30.*
New Orleans 1,729 miles.

Dome is a small place, but Gila City, its predecessor, was a turbulent boom town with a population of perhaps 1,000 people when placer mining was in progress in 1858 and a few following years.

From Dome the railroad passes through Blaisdell, Fortuna, and Araby sidings. To the east are fine views of the steep western front of the Gila Mountains. Twelve miles southeast of Fortuna siding is the old Fortuna mine, which at one time produced considerable rich ore, aggregating, it is reported, $3,000,000 worth of gold (Yearbook of Arizona, 1930). The rocks at this place are mostly hornblende schist, and the gold occurred in included quartzose members. The very pronounced schistosity dips to the south and west at an angle of 45°. Feldspathic dikes cutting the schists appear to be branches of the great intrusive masses of granite that form the higher peaks.

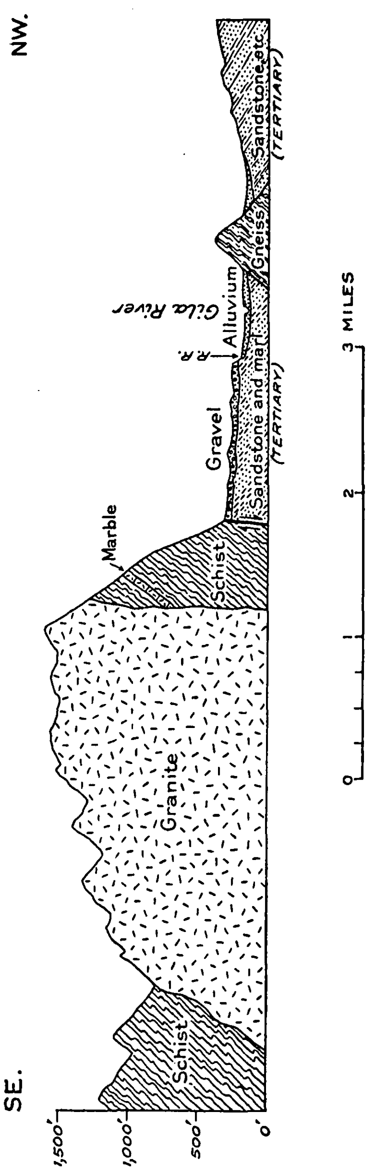


FIGURE 61.—Section of north end of Gila Mountains, Ariz. By E. D. Wilson

After passing the north end of the Gila Mountains west of Dome the railroad bends to the south and in about 6 miles reaches Blaisdell siding. In this bend the railroad follows the south bank of the Gila River. To the north are good views of the eastern part of the Laguna Mountains, which consist of schist similar to the rock on the north end of the Gila Mountains—in fact, the river gorge is simply a gateway eroded across this mass of schist. The western part of the Laguna Mountains consists of a thick body of conglomerate and boulders, probably of Tertiary age. It is separated from the schist by beds of arkose and shales, which crop out on the north side of the river and are also well exposed in slopes and cuts 2 to 3 miles north of Blaisdell. The beds dip 20° SE. and are overlain by terrace gravel of Quaternary age. The arkose is yellow and reddish and made up of granite detritus, in part thin bedded and showing mud cracks on some of its surfaces. Some of the pebbles are half an inch in diameter. A few interbedded strata of shale are of yellowish tint. These beds are probably of Tertiary age. A few sahuaros are present, this vicinity being about the western margin of their wide zone of distribution.

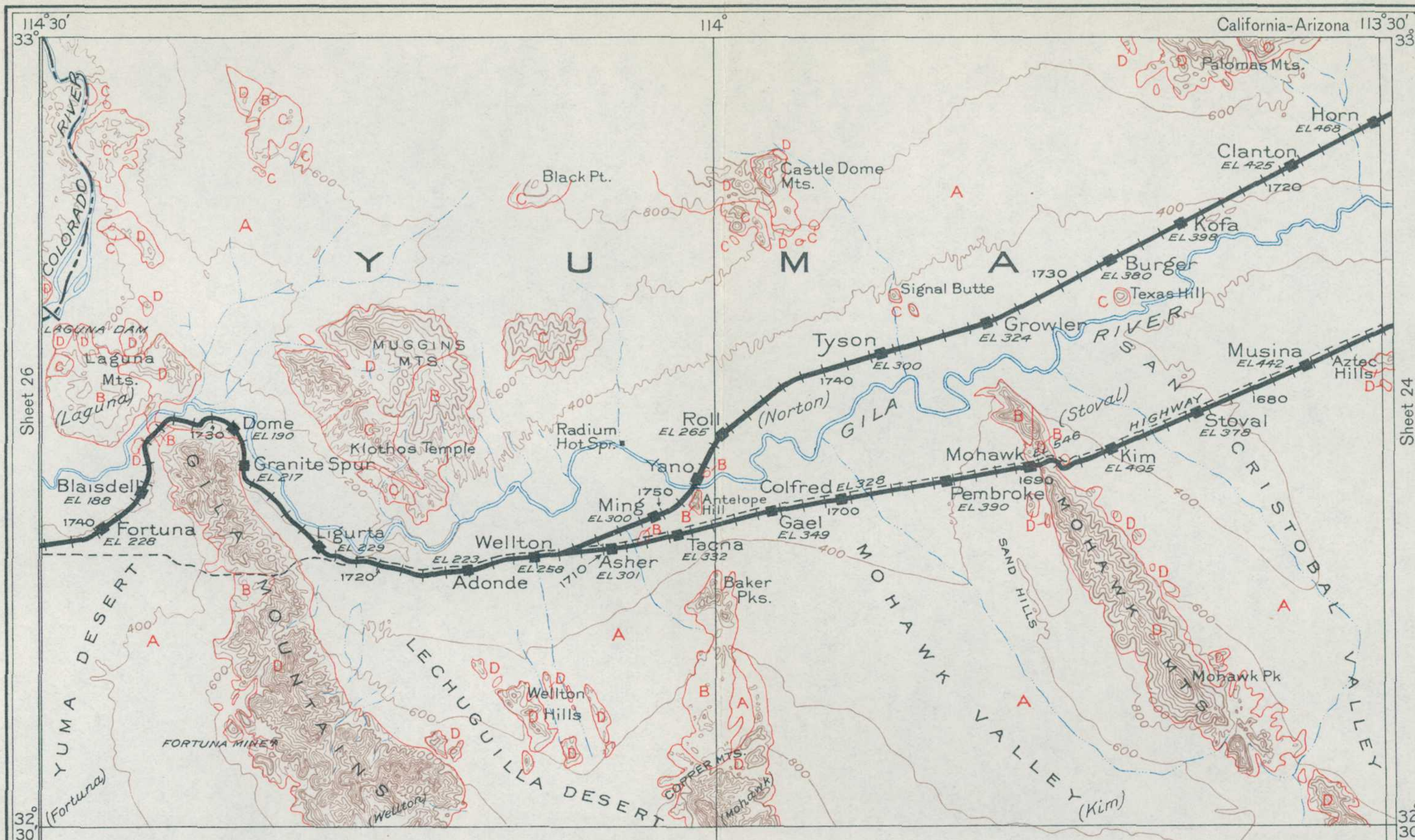
Southwest of Blaisdell siding the railroad leaves the wide trench excavated by the Gila River and ascends about 100 feet to the terrace plain of the Yuma Desert, which extends far to the south and southwest. It continues on this plain to Yuma. From the vicinity of Fortuna and Araby sidings Pinnacle Rock, far to the west in California, is in sight. A large gold mine was formerly operated near this peak. The vegetation on the Yuma Desert is very scant; on the alluvial flat along the river, however, there is considerable irrigation by water pumped from wells of moderate depth in the gravel and sand deposits. (Turn to sheet 26.)

Yuma.
Elevation 142 feet.
Population 4,892.
New Orleans 1,750 miles.

Yuma, one of the oldest towns in the Southwest, long the commercial center for a large surrounding area, and now the headquarters of a productive irrigation project, is situated on the east bank of the Colorado River just below the mouth of the Gila River. The Gila here is in a broad alluvial terraced valley, from which a few low granite knobs protrude, and this rock is reported in deep borings. The bridge abutment at Yuma is on very coarse granite conglomerate of Tertiary age, which also forms the knoll on which the ruins of the old Territorial prison remain. Its components probably were derived from granite knobs in the center of town and to the southeast. This same formation underlies the basalt that caps Black Mesa, west of Laguna Dam, on the Colorado River 10 miles above Yuma.

Yuma is famous for its high summer temperature and large percentage of sunshine, but with the low annual precipitation of 3.1 inches [64] (40-year average), the humidity is so slight that during the greater part of the year the heat is not oppressive. Relying on the almost perpetual sunshine, a hotel near the railroad station formerly bore the striking sign "Free board every day the sun doesn't shine" (pl. 34, *A*).

[64] The precipitation varies greatly from year to year, having been 11.4 inches in 1905 and 0.6 inch in 1899. The greatest amount of rain usually falls in midsummer. Sandstorms occur occasionally, but their importance or danger is greatly exaggerated. The average temperature for 29 years is 72°, with extreme ranges from 20° to 117° in the bottom lands and 29° to 117° on the mesa.



EXPLANATION

A	Sand and gravel (valley fill and terrace deposits)	Quaternary
B	Sandstone, conglomerate and gravel	Tertiary and later?
C	Lavas, ash and tuff (volcanic)	Tertiary and later?
D	Granite and schist	Pre-Cambrian

Geology mostly by E. D. Wilson, 1931

Scale $\frac{1}{500,000}$

1 inch = 8 miles (approximately)

0 5 10 15 20 MILES

0 5 10 15 20 KILOMETERS

Contour interval 200 feet

Datum is mean sea level

The distances from New Orleans, La., are shown every 10 miles, and the crossties are drawn 1 mile apart

Each quadrangle shown on the map with a name in parentheses in the lower left corner is mapped in detail on the U. S. G. S. topographic map of that name

114°30′ 114° 113°30′

Topography: U. S. Geological Survey quadrangle maps

WILLIAMS & HEINTZ CO., WASH., D. C.

The history of Yuma dates back to 1540, when Alarcón came up the Gulf of California and ascended the Colorado River to cooperate with the land expedition of Coronado. In 1700 Padre Kino came down the Gila River to its mouth, where he found, on the Arizona side, a large ranchería of Indians, which he named San Dionisio. The Yuma Indians gave a cordial reception to the first Spanish explorers and missionaries. The Jesuit missionary Jacobo Sedelmaier reached the Colorado River in 1744 and again in 1748. In 1779 Garcés established the Misión de la Purísima Concepción on the west bank of the river opposite the present town. About 53 families of colonists, laborers, and soldiers, appropriating the best lands, settled near by and also at another mission near Pilot Knob, about 8 miles down the river. The Indians occupied palisaded towns and raised melons, squashes, and grain. Although they had previously appeared most friendly and amenable, they were irritated by the failure of the Spanish authorities to fulfill promises, and in 1781 they started an uprising in which Padre Garcés and three other priests and most of their white men associates, to the number of about 46, were slaughtered, including the visiting Lieutenant Governor of Baja California and a dozen of his soldiers who were camped on the Arizona side of the river. The women and children were enslaved. After this one serious outbreak the Yuma Indians did not prove troublesome to the whites. Originally a powerful race, they themselves suffered much in wars with other tribes and in 1857 were almost annihilated by the Pima Indians.

The first military post, then called Camp Calhoun, was established on the west side of the river in 1849 by United States Dragoons, who escorted Whipple's boundary-survey party. In this year also a boat which came down the Gila River from the Pima region was pressed into service as a ferry across the Colorado River, and on this ferry during the gold rush many thousands crossed to California. The fare was $2 for man or animal. Fort Yuma was established on the west side of the river in 1851, when Camp Independence, as it was then called, was moved to the site of the old mission and renamed.

In 1861–62 the region was partly devastated by a flood. The settlement on the east bank of the river, called Colorado City, Arizona City, and finally Yuma, began to prosper in 1864, and in 1871 the county seat was moved there from La Paz, 75 miles up the river. The first steamboat to ascend the river was the *Uncle Sam*, in 1852, built at the head of the Gulf of California. In 1855 several steamboats were running on the river, and in 1857 Lieut. Joseph Ives started from the mouth of the Colorado in a 50-foot iron stern-wheel steamer (pl. 33, *A*) and ascended to the "head of navigation" through Black Canyon, the site of the reservoir to be impounded by the Boulder Dam. (See p. 241.) Freight boats came up the Colorado as late as 1895. The Southern Pacific Railroad reached Yuma from the west on September 29, 1877, and established its station on the east bank, south of the mouth of the Gila, where there had been a few houses since the time of the Gadsden Purchase, in 1854. That place remained the terminus until April 28, 1879, when the tracks were completed to Maricopa. In 1880 connection with the East was effected. Now Yuma is entirely on the Arizona side.

Yuma and its environs have been greatly benefited by the completion of the Yuma irrigation project of the United States Bureau of Reclamation. The water is diverted from the Colorado River at Laguna Dam, 10 miles northeast of Yuma on the California side, begun in 1902, one of the first results of the reclamation act. The dam is 4,780 feet long and raises the stream about 10 feet, creating a long, narrow lake that provides water for 100,000 acres of irrigable land lying partly in Arizona and partly in California. Part of the region is the alluvial flat along the river, including the Yuma Indian Reservation of 8,000 acres on the California side, and part is on the level "mesa" or terrace extending south from Yuma, onto which the water is raised by pumps operated by cheap electric power produced near by.

The mesa division comprises 45,000 acres lying about 80 feet above the valley, of which approximately 15 per cent is now being developed, with 1,400 acres under cultivation and 934 acres producing in 1930. The soil is very sandy, but its deficiency in organic matter is easily remedied by the use of fertilizer. The climate is frostless and well adapted to citrus and other semitropical fruits, which in 1930 yielded a return of $156,265, or nearly $167 an acre. (See pl. 34, *B*.) About two-thirds of the product was grapefruit, of which about 60,000 trees were bearing in 1930. It costs from $8,000 to $10,000 to develop a 10-acre unit. The yield of citrus fruits averages about $50 an acre after 4 years, $163 after 6 years, and $350 after 8 years. The value of all crops of the Yuma lowlands and mesa in 1928 was $5,105,132, or $113 an acre. The total cost of construction of the Yuma project has been more than $12,000,000, but this is being repaid to the Government by the owners of the land. It amounts to $55 to $90 an acre. (U. S. Bureau of Reclamation.)

An interesting engineering feature of this project is the siphon by which part of the water is carried under the Colorado River, an expedient necessitated by the difficulty of carrying a canal across the Gila River, which empties just above Yuma. The water is brought from the Laguna Dam by a canal along the west side of the river; the siphon is 1,000 feet long and 14 feet in diameter and passes 50 feet below the bed of the river. The inlet may be seen just north of the railroad bridge. The Colorado River carries a large amount of silt,[65] but much of this is caught in a desilting basin at the Laguna Dam, so that it does not clog up canals farther down.

The limit of area of farm units is 40 acres. The duty of water averages 3 acre-feet an acre at the farm, and the irrigation season lasts throughout the year. On the rich alluvial bottom lands a great variety of crops is grown, but the principal ones are cotton, alfalfa, millo maize, kafir corn, feterita, wheat, and barley. A yield of 2 bales of cotton to the acre is not uncommon, and alfalfa seed is a profitable product which yields as much as half a ton to the acre from two cuttings. For hay, however, the alfalfa may be cut six or more times a year. There is a large acreage of pecan groves, some of the older trees producing as high as 180 pounds of nuts. The bottom lands are protected from overflow by levees and drained to prevent accumulation of mineral matter by evaporation.

From Yuma a trolley line runs south down the Colorado Valley as far as Gadsden, passing west of the irrigation settlement of Somerton (population 891).

In the valley filling along the Colorado River above the Laguna Dam there is considerable fossil wood, which is often brought into Yuma. The larger logs are a few feet long and less than a foot in diameter. Many of them show grain and ring structure in a very striking manner. They are said to be closely related to some of the present-day desert hardwoods.

YUMA, ARIZ., TO LOS ANGELES, CALIF.

Colorado River.

The Colorado River is crossed on leaving Yuma. This great river rises in the mountains of Colorado and after its junction with the Green River from Wyoming it receives the drainage of a wide area in the high plateaus of Utah, New Mexico, and Arizona. It was discovered by Francisco de Ulloa, who in 1536 ascended the Gulf of California to the great mud flats at the mouth of the river. In 1540 it was explored by Melchor Díaz, who traveled overland from Sonora, Mexico, to the vicinity of Yuma, and by Hernando Alarcón, who came in boats from western Mexico and ascended the river for 15 days, possibly as far as Needles. Early in 1605 Juan de Oñate reached the river in the vicinity of Yuma on a trip from Santa Fe. Owing to the custom of the natives of carrying firebrands in winter with which to warm themselves, Díaz named the stream Río del Tizón (Firebrand River), a name more distinctive than the present one. The name "Rio Colorado del Norte" was first used on Kino's map in 1701. He reached it first in 1699. Padre Sedelmaier was there in 1744. The

[65] According to investigations by the Bureau of Reclamation, in times of freshets the silt may be as much as 2 per cent, but the average amount is 0.7 per cent, or 30 times as much as is carried by the Ohio River.

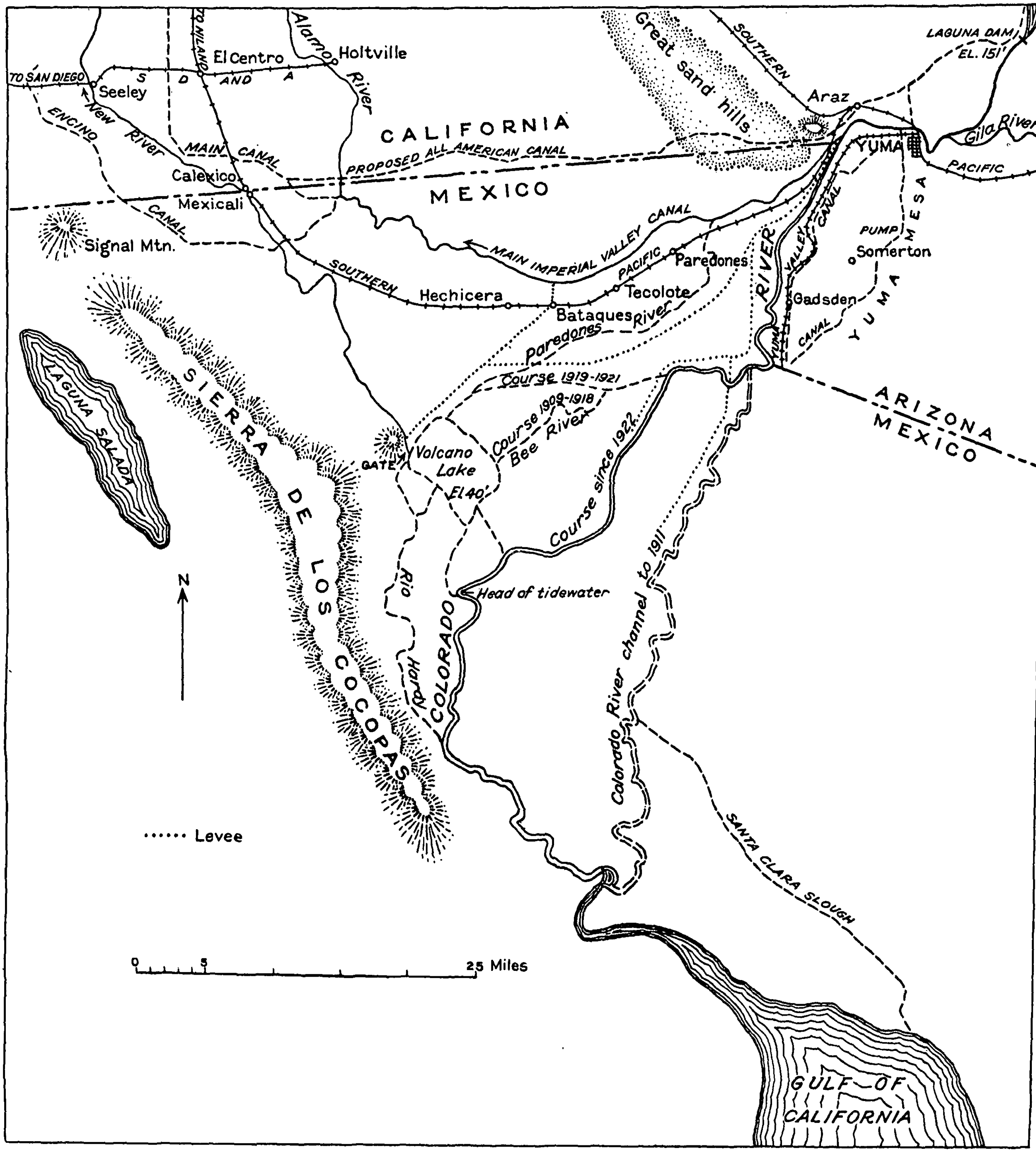
Franciscan friar Francisco Garcés, traveling alone, reached the Colorado in 1771 near Yuma and crossed it on a raft. He crossed it again at that place in 1774 and 1775 with Anza's expeditions.

In the vicinity of Yuma, as elsewhere, the Colorado River meanders through a shallow channel in a wide trench excavated in the great desert plain that extends to the Gila Mountains on the east and constitutes the Colorado Desert and Imperial Valley to the west. The trench or alluvial flat is nearly 5 miles wide at Yuma, where it is bordered by long bluffs of sand and gravel 50 to 100 feet high. The upper part of Yuma is built on the bluff, which is here called "the Mesa." The trench also extends up the valley of the Gila River for many miles. The surface of the alluvial flat is nearly smooth, but in places it slopes slightly away from the river, owing to the low bank or levee built by the stream at times of freshet when there is considerable overflow in places not protected by artificial levees. South of Yuma there are extensive sloughs and oxbow ponds along the principal overflow channels.

The Colorado River empties into the head of the Gulf of California in Mexico about 60 miles below Yuma (see pl. 35), and in fact this large water body is an extension of the Colorado Valley submerged by tidewater. The volume of the river varies considerably, and at times it is greatly swollen by freshets. The floods occur mostly in early summer and are fed by winter rains and snows in the distant mountains. The highest summer floods have exceeded 200,000 second-feet (cubic feet per second). The ordinary maximum flow is 70,000 to 100,000 second-feet, the minimum flow, 2,500 to 3,000 second-feet, and the average 10,700 second-feet. In August, 1931, the flow at Yuma decreased to 200 second-feet (U. S. Bureau of Reclamation). The total yearly flow at Yuma averages about 16,730,000 acre-feet (1902–1916) including 1,000,000 acre-feet or more from Gila River. The mineral content of the water ordinarily ranges from 1,000 to 350 parts per million,[66] and it is estimated that the sediment in suspension is sufficient to cover about 100,000 acres 1 foot deep (100,000 acre-feet) annually. Considerable sediment is also moved along the bottom of the river. The material spread on the land by overflow has important fertilizing value. (U.S. Bur. of Reclamation).[67]

[66] A very large amount of material is removed from the land and carried to the ocean by all rivers. Careful estimates based on analyses of river waters and measurements of volume of flow have shown that every year the rivers of the United States carry to tidewater 513,000,000 tons of sediment in suspension and 270,000,000 tons of dissolved matter. The total of 783,000,000 tons represents more than 350,000,000 cubic yards of rock, or a cube measuring about two-fifths of a mile on each side (1/15 cubic mile). The total is equivalent to 610,000,000 cubic yards of surface soil. (See U. S. Geol. Survey Water-Supply Paper 234, p. 83, 1909.)

[67] See also Bacon, J. L., Monthly Weather Review, vol. 59, pp. 295–297, 1931; Breazeale, J. F., Arizona Univ. Bull. 8, 1926; Forbes, R. H., Arizona Univ. Bull. 44, 1902.



MAP OF THE COLORADO RIVER DELTA REGION, BELOW YUMA, ARIZ.

An important engineering project in connection with the Colorado River is the Boulder Dam, in Black Canyon, 200 miles above Yuma (about 15 miles below Boulder Canyon), which was started in 1931. It will completely control the waters of the river and not only maintain the supply as needed, but prevent floods and greatly diminish the amount of silt. According to printed statements of the United States Bureau of Reclamation the dam will be a curved gravity structure about 1,180 feet long and will contain approximately 3,500,000 cubic yards of concrete requiring about 5,500,000 barrels of cement. Its height will be 707 feet above bedrock; this will raise the water surface about 582 feet, or to 1,229 feet above sea level. The reservoir, 115 miles long and with an area of about 145,000 acres (227 square miles), will hold 30,500,000 acre-feet of water. It will take a year and a half for the river to fill the reservoir under ordinary conditions of flow. The cost of the dam will be about $70,600,000, not including a 1,200,000-horsepower electric generating plant ($38,000,000), the revenue from which, together with the charge to irrigators for the water, is expected to cover the interest and finally repay the cost. An all-American canal 75 miles long, provided for by an allotment of $38,500,000, will be built through the sand hills that begin 10 miles west of Yuma, to replace the present canal, which for 35 miles is in Mexico. Its cost also must be repaid by the irrigation under it. This canal, with a bottom width of 134 feet and a depth of 22 feet, will supply a much larger volume of water than is now flowing in the old canal, which is the largest one in operation in this country, and will provide for greatly increasing the irrigated area in Imperial Valley. The water will be taken from the river at a point 5 miles above the present Laguna Dam, a few miles above Yuma. It is estimated that a branch 130 miles long to provide for irrigation in the Coachella Valley and increasing the area irrigable under this project to 900,000 acres, will cost about $11,000,000. Los Angeles will also receive some of the water (1,500 second-feet), which will be taken out at Parker and carried through long aqueducts and tunnels by way of San Gorgonio Pass.

From a point 6 miles west by south from Yuma the middle of the Colorado River is the boundary between the United States and Mexico, Arizona extending about 16 miles farther south than California. By the treaty of Guadalupe Hidalgo, in 1848, the original international boundary followed the Gila River to its junction with the Colorado and thence was a straight line west to a point on the Pacific Ocean 1 marine league south of the southernmost point of the port of San Diego. By the Gadsden Purchase the southern boundary east of the Colorado River was shifted to its present location, which touches the Colorado at a point 20 English miles below the junction of the Gila. North of Yuma the Colorado is for many miles the dividing line between Arizona and California.

California, the largest of the three Pacific Coast States, has a length of 780 miles and width of about 250 miles. The area is 158,297 square miles, nearly equal to New York, New England, and Pennsylvania combined. The population of California in 1930 was 5,677,251, or about one-fifth of that of the Eastern States named. This was a gain of nearly 66 per cent in the 20 years from 1910 to 1930. The average number of persons per square mile was 36.5, as compared with 22 in 1920. The population is very unevenly distributed, however, the desert regions east of the Sierra Nevada being very sparsely occupied. The State has 1,264 miles of coast line, mostly bold and unbroken but indented by the fine harbors of San Diego and San Francisco.

California.

California has a great range in elevation, for some of its desert valleys are below sea level and much of the Sierra Nevada is more than 10,000 feet above sea level, the highest peak, Mount Whitney, reaching 14,496 feet. The lowest places are Death Valley, the bottom of which is 276 feet below sea level, and the Salton Basin, the bottom of which (when dry) is 273.5 feet below sea level. Owing to its great range of elevation and latitude, California presents a wide diversity in climate, with corresponding variation in vegetation and animal life. Along the coast in southern California precipitation is low and temperatures are equable. Around San Francisco Bay the moderate rainfall comes almost wholly in the winter, and the seasonal range of temperature is comparatively small, although from hour to hour the change is sometimes very marked. In parts of southern California typical desert conditions prevail. The great interior valley of the San Joaquin and Sacramento Rivers is characterized by moderate to scant winter rainfall and hot, dry summers. Snow rarely falls except on the adjoining high mountains.

Forests cover 20 per cent of the State. They are notable for the large size of their trees, especially for the huge dimensions attained by two species of redwood—*Sequoia washingtoniana* (or *S. gigantea*), the well-known "big tree" of the Sierra Nevada, and *Sequoia sempervirens*, of the Coast Ranges. Some of these giant trees have fortunately been preserved against the inroads of the lumberman by the Government or through private generosity. The 21 national forests in California have a total area of 40,000 square miles, or about one-fourth of the State's area. The national parks in the State are the Yosemite (1,124 square miles), Sequoia (252 square miles), General Grant (4 square miles), and Lassen Volcanic (124 square miles).

Agriculture is an enormous industry in California, and its importance is increasing. The following facts from the United States census reports are of interest: Of the total land area of nearly 100,000,000 acres, about 30,442,581 acres is in farms and ranches, which with buildings and machinery have a value of nearly $4,000,000,000.

More than 4,000,000 acres is under irrigation. The value of crops in 1929 was $623,103,467, the cost of which for labor and fertilizer was $212,417,664. The grain crop in 1929 was 48,451,246 bushels, of which about three-fifths was barley. The cultivated hay crop for 1929 was 4,098,993 tons, and the cotton production 253,881 bales. In the variety and value of its fruit crops California outranks all other States. Its products range from dates, figs, pineapples, and other semitropical fruits in the south to pears, peaches, apples, and plums in the north; but it is to oranges and other citrus fruits and grapes that California owes her horticultural supremacy. During 1929 California produced 53,820,634 boxes of citrus fruits, 37,738 tons of walnuts, 4,700 tons of almonds, 1,691,111 tons of grapes, of which more than half were of the raisin variety, and great quantities of prunes, peaches, apricots, olives, and melons. Other notable crops are hops, about 7,905,965 pounds in 1929; lima and other beans, 5,526,351 bushels; sugar beets, 452,818 tons; potatoes, 6,489,203 bushels; and wheat, 10,957,967 bushels. The total value of vegetables shipped in 1929 was about $60,272,659. More than 5,000 acres is in strawberries, and the fig crop in 1929 was more than 59,000 tons. California leads in apiculture, producing about one-tenth of the Nation's honey, the amount being normally about 6,000,000 pounds, besides 300,000 pounds of wax. Much honey is exported from Los Angeles. There are about 150 species of plants that furnish nectar in important amounts; the blossoms of oranges and sagebrush are the most reliable sources. The yield of honey is closely related to the amount of rainfall. Many of the bee colonies are moved from place to place to take advantage of blossoming periods, not only for the honey obtained but for service in pollenization. Dairying is an important industry, with a yield of 445,530,000 gallons of milk in 1929. In 1930 the wool clipped amounted to 18,747,453 pounds. Cotton, melons, and dates are raised abundantly in the irrigated districts in the southeast corner of the State, and rice production is increasing rapidly.

Of its mineral products, petroleum ranks first in total value, and gold next. According to the United States Bureau of Mines, California's output of petroleum was 227,329,000 barrels in 1931 (292,036,911 barrels in 1929), about 16 per cent of the world's yield, and its output of gold amounted to about $8,455,200. Other mineral products are cement, 13,091,899 barrels; copper, 33,084,232 pounds; silver, $636,749; mercury, 10,139 flasks (of 76 pounds); and borate minerals, 169,870 tons, valued at $4,515,375. The total value of products from California mines and quarries in 1929 was $38,645,889, with a personnel of more than 9,000. The leading industry is refining petroleum, the products of which in 1927 were valued at more than $350,000,000. California's fisheries are also a source of much revenue. According to the United States Department of Commerce, the exports from San

Francisco, Los Angeles, and San Diego had a value of $377,392,437 in 1929, and the annual imports amount to nearly $300,000,000, of which more than half passes through San Francisco. There are in the State four great universities—the University of California (enrollment 19,000), Leland Stanford Junior University (4,600), the University of Southern California, and the California Institute of Technology—besides many smaller collegiate institutions.

The recorded history of California began in 1542, when Juan Rodríguez Cabrillo explored the southern coast. Sir Francis Drake, who landed on California soil in 1579 to repair his ships, named the place New Albion, but later the name California was applied. It is claimed that this name was derived from Califa, queen of the Amazons, used by Montalvo in a romance, but also that it was taken from the name given by Cortez to the south end of Lower California and meaning fiery furnace. Until Padre Kino's explorations in 1700 and 1701, California was supposed to be an island. In 1602–3 Sebastian Viscaino discovered the sites of San Diego and Monterey. From 1769 to 1823 21 missions were established in California under the direction of the Franciscan friar Junípero Serra and other missionaries of his order, and most of them still remain, although some are in ruins. The first overland caravans to California began in 1827, and the discovery of gold by J. W. Marshall at Sutter's mill in 1848 brought a large influx of gold seekers and settlers.[68]

California was formerly a part of Mexico, but many citizens of California were Americans and strongly desirous of entering the Union, especially as trouble with Mexico increased. On July 7, 1846, the American flag was raised in Monterey, and the annexation of California proclaimed. The treaty of Cahuenga, negotiated by Gen. John C. Frémont and the Mexican commander, Andrés Pico, and signed on January 13, 1847, ended hostilities, and in 1850 California was admitted to the Union as the thirty-first State. The official State flower is the California poppy (*Eschscholtzia californica*), and the State's motto, "Eureka," means "I have found it."

On leaving Yuma the railroad crosses the Colorado River on a long bridge (see p. 236) and curves around to the northwest to traverse the alluvial plain of the river, here nearly 5 miles wide. This land is included in the Yuma Indian Reservation, 8,350 acres in all, which is supplied with water for irrigation by a canal from the Laguna Dam, 10 miles above Yuma. (See p. 238.) This canal, crossed not far beyond the river bridge, was one of the early irrigation projects of the United States Bureau of Reclamation, having been completed in 1909. About 1,500 acres is under cultivation, yielding crops of various kinds, notably cotton, which thrives on the rich sandy soil. Much

[68] The first discovery of gold was made in Placerita Canyon, near Los Angeles, in 1842, but it had little economic importance.

alfalfa is also raised. A view of part of the irrigated district is shown in Plate 34, *B*. The Indians who occupy this reservation form a picturesque element among the various people who make up the population of the Yuma region. Usually the day trains in Yuma are met by Indian women offering beads and other trinkets. The Yuma Indians have cultivated the river flats for many centuries but retain many primitive methods. The Fort Yuma Indian School, a prominent building on the farther bank of the river, has an attendance of about 200. A statue of Garcés in front of the chapel here commemorates the heroic Franciscan who, after martyrdom at his mission here in 1781, was interred with respect by the Indians who had murdered him. His body was later transferred to Mexico. (See p. 187.) Kino estimated that there were 6,000 Yuma families. It has been estimated that there were 3,000 Indians here in 1853; in 1932 there were 842 under the Fort Yuma Agency. The word Yuma, from "Yahmayo," son of the captain, was applied erroneously by the early Spanish missionaries; the Indians call themselves Kwichân.

Araz.
Elevation 156 feet.
New Orleans 1,756 miles.

A mile west of Araz siding the San Diego & Arizona Railway, a part of the Southern Pacific system, branches to the southwest and goes by way of Mexicali, Calexico, and El Centro, across Imperial Valley, and through the beautiful Carrizo Gorge to San Diego. (See p. 287.) Near Araz the railroad reaches the western edge of the river flat and begins an ascent of about 150 feet onto the higher terrace or general desert level. On this grade it passes through long, deep cuts exhibiting the nature of the sand and gravel deposits that make up the terrace. At one point this material is extensively quarried for road making. Half a mile beyond the siding, on the south side of the highway, south of the tracks, are the ruins of the old Araz stage station on the river bank, constructed in 1856. The material is adobe.[69]

From a point near this place a branch road follows the west side of the Colorado River, which here makes a great bend to the south and in less than 3 miles enters Mexico near the village of Algodon.

Southwest of Araz siding is the isolated Pilot Knob, or Cerro de Pablo, near the west bank of the river, consisting of a mass of lava lying against granite and schists. Near it in 1780 was established the mission of San Pedro y San Pablo de Bicuñer under the administration of Padre Garcés. The colony consisted of 20 settlers, 21 soldiers, and 12 laborers, with their families. In the Indian revolt of the following year two resident missionaries and practically all the soldiers and colonists were clubbed to death, and the women and children were made captives. On the slope of Pilot Knob dur-

[69] In the West the term "adobe" (colloquially "doby") is commonly used both for the sandy clay from which these sun-dried bricks are made and for a structure made of them.

ing the gold rush of 1849 a stone structure called Fort Defiance was built by Americans in connection with a ferry across the river near by. It was soon abandoned after a massacre by the Yuma Indians.

As the level of the general desert plain is attained near Knob siding many prominent mountains come into view—the rough ridges of the Cargo Muchacho Mountains near by to the north, a group of high ridges surrounding the sharp Picacho Peak to the northeast, and various high ranges back in Arizona. Some of these mountains consist in whole or in part of volcanic rocks; others are made up of old gneisses and granites, such as constitute the Gila Mountains. A group of rocky knobs of vesicular lava, skirted 2 miles southeast of Ogilby siding, has been a source of railroad ballast. On approaching Ogilby the Cargo Muchacho Mountains seem near. They consist of schists and include a number of mines, old and new. The principal old one, the American mine, was worked from 1879 to 1918, with a production locally estimated at several million dollars. Near by are the ruins of Tumco (formerly Hedges), a town which had a population of nearly 1,000 when the mines were operating. The ore was in veins in pegmatite, which cuts the schist in every direction.

Ogilby.
Elevation 356 feet.
New Orleans 1,776 miles.

Three miles north of Ogilby is a mine producing cyanite, a very refractory aluminum silicate that is useful in the manufacture of high-grade porcelain ware, electrical insulators, and refractory brick and shapes for the glass and iron industries. This mineral, which is of a beautiful blue color, occurs in a large vein with quartz, in mica schist. It is shipped to Los Angeles for the separation of the quartz and preparation for the market.[70] A mile north of the cyanite mine talc is mined, for use largely in paper manufacture.

West of Knob siding and extending from the Mexican boundary to and beyond Amos siding, a distance of 50 miles, is a wide belt of sand hills which is more familiar to most persons than they are aware, for it has afforded the background for many "Sahara Desert" scenes in the moving pictures. The belt is about 5 miles wide. It presents a picturesque succession of shifting dunes, of loose pale-yellow sand, in places 200 to 300 feet high, separated by irregular basins. The highway to El Centro formerly passed over this sandy strip on a road made of heavy planks strung together with wire. It was 10 feet wide, with passing places at intervals. In 1928 this unique roadway was displaced by a wide concrete highway suitable for the present heavy

[70] Cyanite is of the same composition as andalusite and sillimanite, consisting of alumina 62.85 per cent and silica 37.15 per cent, the proportion of alumina being considerably greater than in clay. The separation of the fibrous cyanite from the quartz is effected by an ingenious process of heating to 1,800° F. and chilling in water, which shatters the quartz so that it can be removed by washing and screening.

traffic of Imperial Valley. This sand-dune belt is one of the largest inland occurrences of its kind in the United States. Doubtless the dunes are still shifting somewhat, but as land surveys of 1856 show practically the same configuration as the present one, the change must be slow, and probably many hundreds of centuries has been required for their accumulation. They are a serious barrier to canal construction, as the sand is loose and drifts extensively, but in 1931 provision was made to build an all American canal through them to supply water to Imperial Valley without the deflection into Mexican territory which the old canal makes.

From Ogilby northwestward the railroad passes between the sand-hill belt and the long slopes that lead up to the mountains to the northeast. At Glamis a road to Blythe leaves the railroad and proceeds to a distant pass up the Palo Verde Valley (pah'lo vare'day), a wide dry wash which rarely carries any water. As the rainfall in this region is very low, an average of about 3 inches a year, vegetation is sparse and closely adjusted to soil conditions. Ironwood (*Olneya tesota*) and the creosote bush (*Covillea*) are the most noticeable features in the vegetation; ocotillo is conspicuous in places. Some of the ironwoods are 20 feet high, but they are widely separated. Northwestward from the gap northeast of Glamis the Chocolate Mountains[71] make a high continuous wall extending for 20 miles as a succession of prominent ridges rising abruptly from the valley, 3 to 8 miles northeast of the railroad. In these mountains there have been a few notable mines, including the Paymaster and Pegleg, both of which were good producers of silver-lead ores years ago. At the east end are some outlying buttes capped by basalt, and in part of the range and in foothills on its south side are andesitic and rhyolitic lavas of Tertiary age. It has been suggested that the steep south front of the range in this vicinity was determined by a fault; granite and basalt occur in small foothills south of the main range.

Glamis.
Elevation 338 feet.
Population 15.*
New Orleans 1,785 miles.

On the south side of the railroad is the great sand-hill belt (see pl. 36, *A*), on the farther side of which is Imperial Valley.

There is a down grade from a point near Glamis westward, and the tracks pass below sea level near Flowing Well siding. This place

[71] The Chocolate Mountains consist mainly of granite, but schist also occurs, and these old rocks are overlain and flanked in places by lavas of Tertiary age. In Iris Pass, which crosses the range north of Niland, there are Tertiary strata consisting of steeply tilted beds of sandstone, conglomerate, and yellow clay, lying on light-colored igneous rocks. Near the upper end of the canyon leading to this pass beds of white soft tuff give place to a vertical mass of dark rhyolitic breccia in which the canyon narrows greatly. On each side of this mass are beds of conglomerate which appear to lie nearly horizontal and contain boulders of rhyolite and other volcanic rocks. West of the pass granite is the principal rock, constituting a high rocky range. (Brown.)

owes its name to the former presence of a marsh and a pool of brackish water of unknown origin. A short distance beyond is the East Highland Canal, which carries irrigation water along the east margin of Imperial Valley as far as Niland. From the canal crossing there is an excellent view of the beach of the old Lake Cahuilla, which once occupied the Salton Basin. (See p. 253.) The beach, which consists of sand, here forms a steep bluff about 40 feet high and extends far to the southeast along the east side of the canal.

Niland.

Elevation—127 feet.
Population 200.*
New Orleans 1,815 miles.

Near Niland outcrops of soft sandstone appear in low ridges constituting the north slope of Imperial Valley. The sandstone is interstratified with shale, clay, and conglomerate, the conglomerate mostly as a basal member. These rocks are of Miocene or Pliocene age and steeply tilted. They crop out almost continuously on the northeast side of the railroad to Indio and beyond. From Niland, formerly called Imperial Junction, a branch railroad leads south to Brawley, El Centro (32 miles), and Calexico (41 miles), in Imperial Valley. In the eastern part of Niland the railroad is crossed by the power line that furnishes electricity to Imperial Valley. The current is generated by water power in Owens Valley, 300 miles to the north. The line extends northwestward a short distance north of the railroad, to Indio and beyond.

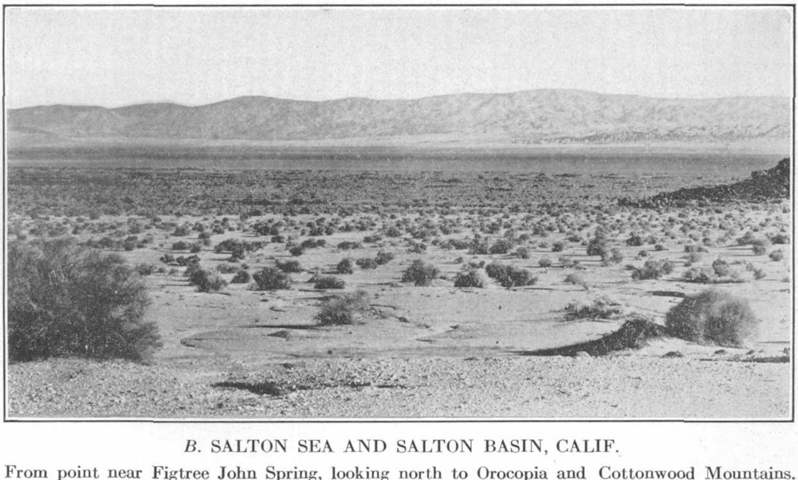
Imperial Valley has an area of about 600 square miles, occupying the central part of Imperial County southeast of Salton Sea. Most of it lies 10 to 175 feet below sea level. The parallel of 33° north latitude passes through its center, and with the low elevation and this southern location it has a warm climate that is highly favorable for the growth of many valuable crops. With a large supply of water taken from the Colorado River and some water pumped from wells, irrigation has made this area one of the most productive agricultural districts in the world. The principal towns are El Centro, Calexico, Brawley, Imperial, and Holtville, in California, and Mexicali, in Mexico. The irrigable area is about 500,000 acres in the United States and a large district in Mexico, and at present about four-fifths of it is under cultivation. The population is about 70,000.

The water is taken from the Colorado River near Yuma in a large canal that passes south around the southeast end of the sand hills and then west through Mexico for about 35 miles before swinging back into the United States, which it reenters at a point south of Holtville. (See pl. 35.) The portion of this canal in Mexico is controlled by a Mexican syndicate that draws heavily on the water supply.[72] In

[72] The amount of the water of the Colorado River to be allotted to Mexico is somewhat of a problem. The American members of the International Water Commission have suggested 750,000 acre-feet a year, which is more than has ever been utilized in the area in Mexico, but the Mexican members desire nearly five times as much, or one-fourth of the total annual content of the

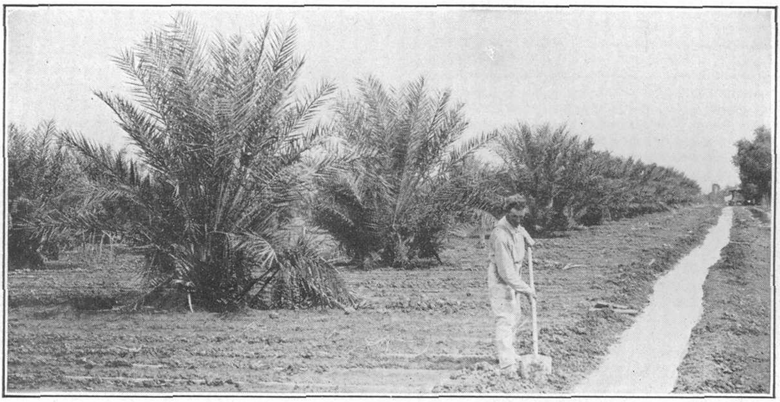
A. DRIFTING SANDS NEAR NORTH END OF SAND HILLS NEAR AMOS SIDING, CALIF.

Chocolate Mountains in background. (Mendenhall.)

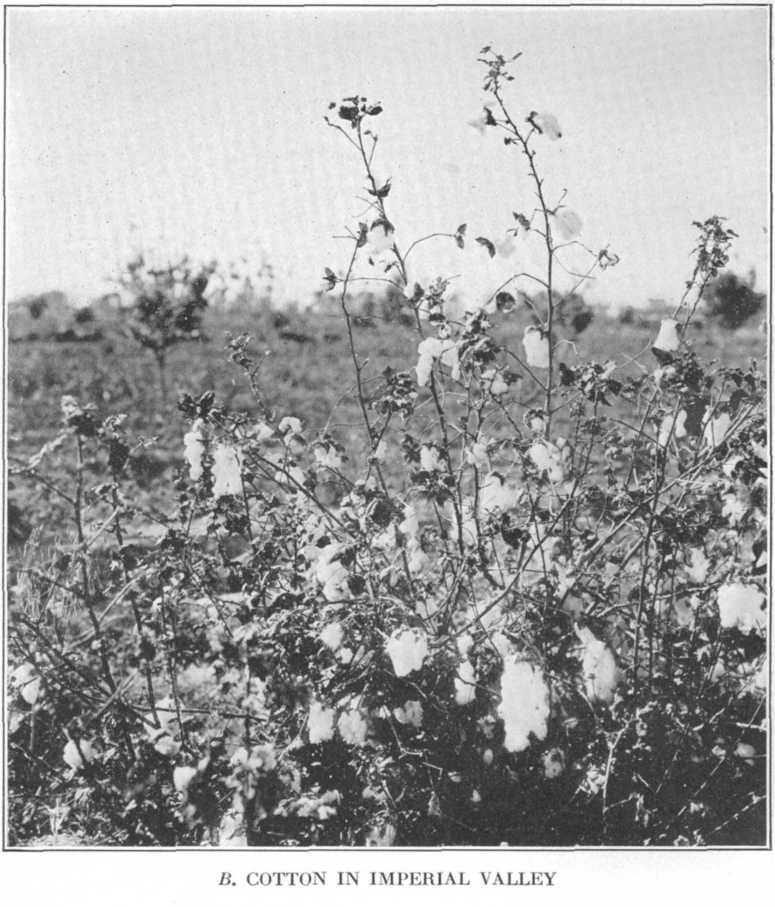


B. SALTON SEA AND SALTON BASIN, CALIF.

From point near Figtree John Spring, looking north to Orocopia and Cottonwood Mountains. (Mendenhall.)



A. IRRIGATING YOUNG DATE PALMS IN IMPERIAL VALLEY, CALIF.



B. COTTON IN IMPERIAL VALLEY

connection with the Boulder Dam project the supply will be provided by an all-American canal. (See p. 241.) The cost of the irrigation system in Imperial Valley has been about $18,000,000. The crops raised are most varied, with 112,432 acres of alfalfa, 22,165 acres of cotton (see pl. 37, *B*), and a large acreage of fruits and vegetables, including 8,000 acres in grapefruit and 70,000 acres in melons of various kinds. The yearly value of its products is locally claimed to be between $40,000,000 and $50,000,000. Cotton, dates, citrus fruits, barley, and alfalfa grow side by side. From Imperial Valley New York gets its earliest cantaloupes, of which it is locally estimated that about 20,000 cars are shipped each year, and 15,000 carloads of lettuce were shipped to the eastern markets in 1926. The grapefruit crop in 1929, according to the United States Census, was 329,461 boxes, and the grape crop 4,032 tons. Alfalfa yields 7 to 10 tons to the acre for each cutting, and it is harvested several times a year. Livestock and dairying are important industries which utilize the pasturage and forage products to great advantage. It is locally estimated that 16,000,000 gallons of milk was produced in 1929.

The United States Department of Agriculture has made a detailed study of the soils of an area of 1,100 square miles in Imperial Valley, or most of that portion of the irrigable area that lies within the United States. All of the material is alluvium derived from the Colorado River, and although most of it is suitable for agriculture, some areas are too much mineralized for most plants, and others are suitable only for certain crops. Irrigation also adds to the mineralization unless precautions are taken to avoid accumulation of saline matter by evaporation, for river water contains considerable of it in solution.

Imperial Valley has a very warm climate for a large part of the year, but temperatures rarely rise above 125°, and the mean is about 70°. With very low humidity the warmth is more bearable than sultry heat in other regions. In winter the minimum has been as low as 19°, but temperatures below 32° are rare and of short duration. The mean annual rainfall is somewhat less than 3 inches. The climate in general is closely similar to that of much of the Nile Delta, but the average humidity is only about two-thirds as great and is much less variable. Dust storms, which occur mostly in February, March, and April, are short but trying.

Prof. W. P. Blake, of the Government expedition of 1853, was probably the first to recognize the agricultural capabilities of the lower part of the Colorado Desert and to suggest that the water of the Colorado River could be utilized for its irrigation. A few years later

river. In some years of scanty flow, such as 1930 and 1931, Imperial Valley could scarcely obtain a daily mean of 1,000 second-feet, although the requirements are 2,500 second-feet. (Homan, P. T., Economic aspect of the Boulder Dam project: Quart. Jour. Economics, vol. 45, pp. 177–217, 1931.)

surveys were made for a canal, and in 1859 the State of California petitioned the United States Government to cede 3,000,000 acres of the land for development. In 1875–76 surveying parties reported favorably on a diversion canal passing through Mexico, on practically the present route of the main canal, but no concessions were granted, and it was not until 1900 that the canal was begun under private auspices. In 1901 water was available, and the excellent results obtained encouraged a large influx of settlers. The alluring but well-fitting name Imperial Valley was given to the region, and its development has been rapid and extensive. There were many difficulties to overcome, such as rapid silting of the canal near the headgates, but the worst setback was the breaking of the Colorado River into the intake below Yuma in 1904 and 1905. The great river, swollen by a winter flood, abandoned its own bed and flowed into the Salton Basin through the old watercourses, the Alamo and New Rivers, excavating wide channels. With this influx of the river the Salton Sea grew rapidly into a great fresh-water lake, and large areas of valuable lands and canals were destroyed. It was seen at once that unless the flow could be stopped Imperial Valley was doomed. A brush mat and piling dam was started after the summer flood had subsided, but a later flood destroyed it, and other floods added to the difficulty. Late in 1906 the Southern Pacific Co. took control of operations, and after one disheartening failure, the use of vast amounts of rock brought from quarries was effective in closing the break in February, 1907. The cost of this work was estimated at $3,000,000. The flooding of Salton Sea necessitated the removal of 67 miles of railroad tracks, in places as much as 2 miles, to their present location.

This flooding was facilitated by the high gradient of 200 feet or more in the valley, which gave the water greater declivity than its own low gradient down the old main channel to the Gulf of California. Soon the greater part of the river's flow was entering the basin, and in a year or more Salton Sea had increased in length to 45 miles and in width to 17 miles, with a depth of 67.5 feet and an area of 443 square miles. Its northwestern margin extended nearly to Mecca and its eastern margin encroached on Imperial Valley. Had the water risen much higher the great irrigation settlement would have been inundated.

When the inflow was stopped, in February, 1907, evaporation began at once to reduce the lake, and in the next five years the level fell 25 feet. This fall of 5 feet a year was less than the average annual evaporation (about 9½ feet), for some water is received from the overflow and seepage of irrigation ditches and some through drainage from the surrounding mountains. In 1915 the depth of the water had diminished to 38 feet, and in 1919 to 30 feet. In the last decade the water level has ranged from 250 feet below sea level in 1923 and 1925 to 245 feet below in 1930.

Within two and one-half years after the Salton Sea was flooded its water was four times as saline as that of the river from which its water was derived. When the water receded and revealed a portion of the bottom of the basin it was found that several feet of silt covered the old salt deposit on its floor.

It has been estimated that during the time of their overflow into the Salton Basin the Alamo and New Rivers removed from their beds and banks 450,000 cubic yards of material in nine months. At this time the Alamo River developed a waterfall 30 feet or more high, which for a while cut backward at the rate of 1,400 feet a day.

Outside of the irrigated area this basin is part of the most arid desert in the country. It was called by the Mexicans and Indians "La Palma de la Mano de Dios" (the hollow of God's hand) and was named the Colorado Desert by W. P. Blake in 1853, eight years before the State of Colorado was named. At present the name Imperial Valley is used for the eastern part of the area, Salton Basin for the central area, and Coachella Valley for the upper part from the head of Salton Sea to the foot of San Gorgonio Pass. It is an inland extension to the northwest of the valley that holds the head of the Gulf of California and comprises more than 2,000 square miles between the Santa Rosa Mountains and Peninsular Range on the southwest, and the Chocolate, Orocopia, and Little San Bernardino Ranges on the northeast. It is followed for more than 150 miles by the Southern Pacific Railroad.

Structurally this area is a complex downfaulted block of the earth's crust, deeply floored by Tertiary sediments and alluvial deposits. Its lowest part is now 273.5 feet below sea level. Its main outlines apparently were developed in Tertiary time, for it contains extensive deposits of Tertiary age, and these have been flexed and faulted. They comprise Miocene or Pliocene marine beds, overlain by subaerial beds that were formed in a desert basin somewhat like the present one. Since that time, however, the basin has been greatly uplifted, for part of the Tertiary strata have been eroded down to a level far below the present valley bottom. It has been suggested that the basin was occupied until recently by an extension of the Gulf of California, which was cut off by the building of a delta by the Colorado River, but recent investigations seem to indicate that much of the present depression below sea level was effected by crustal movement after most of the Colorado River delta was built, and therefore long after the invasion by the sea. Blake discovered that in relatively recent time the basin was occupied by a transient fresh-water lake of large extent, which he called Lake Cahuilla (ca-wee'ya). (See p. 253.) The delta cone of the river, which now cuts off the basin to the southeast, is young, however, and its top is only about 30 feet above sea level. That there has been recent faulting in part of the basin is shown by a very fresh fault cliff or rift in the surface (see pl. 39) and by occasional earthquakes. As the great river carries a heavy load of sediment (see p. 240), it is reasonable to believe that it would be able to build a delta all the way from Yuma to the head of the Gulf of California at a rate equal to a slow subsidence. The salt in the present Salton Basin [73] is believed to have resulted solely from the evaporation of river water and of transient streams running into the basin. The capacity of the Salton Basin up to the lowest point in the delta rim to the southeast, 30 feet above sea level, an area of about 2,100 square miles, is 264,500 square mile feet (square miles 1 foot deep). (Brown.) With an average annual flow at Yuma of 26,000 square mile feet, the water of the Colorado River, if it all entered the Salton Basin, would supply this volume in about 10 years, but evaporation would greatly retard and possibly prevent complete inundation.

The Salton Basin is in many ways similar in configuration to other closed basins in arid regions. The central portion is flat, and about its borders are alluvial slopes extending to the foot of the mountains, which rise very abruptly with steep rocky slopes. A few rocky buttes or ridges rise above the basin floor somewhat like rocky islands in the sea. The lower part of the basin is filled and floored with a thick body of sand and silt which has been penetrated by borings, some of them 1,000 feet deep, without reaching bedrock, although they may reach formations of Tertiary age. The bottom of the basin is now occupied by Salton Sea. On the east side of the basin are the delta deposits of the Colorado River several hundred feet thick, which consist largely of fine sand and silt. Wells near Holtville are 500 to 800 feet deep in sand and gravel, the lower part of which may possibly be of

[73] This salt was a residue left in the bottom of the basin by the evaporation of the water and was in crusts 10 to 20 inches thick; there also were layers of various thickness in the mud below. Before the inundation of 1891 salt in considerable amount was obtained at a salt works in the bottom of the basin and shipped from old Salton siding. For centuries before, however, this salt had been utilized by the Indians. The fresh waters flowing into the basin brought the salt but contained only a very small proportion, and it has been concentrated by evaporation. A 300-foot boring at the old salt works revealed 270 feet of hard clay below the salt and mud, a deposit of earlier overflow of the basin. Emory in his exploration of 1848 found in the bottom of the basin a very shallow, highly saline pond less than 1 mile in length.

An analysis of the water of Salton Sea made by Earl B. Working in June, 1923 (Carnegie Inst. Washington Yearbook 22, p. 66, 1924), shows a concentration of nearly 39,000 parts per million of dissolved mineral matter. This mineral matter consists mainly of sodium chloride with considerable amounts of calcium, magnesium, and sodium sulphates.

Of course with continued concentration the water becomes increasingly mineralized. At the time of maximum inundation in 1907 the mineral content of the water was only about 3,000 parts per million.

Tertiary age. In the western or upper part of the basin there is much coarse material and sand deposited by streams from the adjoining steep mountain slopes. In places the sands are blown into dunes, which occupy areas of considerable extent.

The beach line of the large prehistoric water body known as Lake Cahuilla [74] is plainly visible at many places along the margin of the Salton Basin and extending up the Coachella Valley [75] to a point about 2 miles above Indio; it extends along both sides of Imperial Valley and southward into Mexico. The surface of the water was about 40 feet above the present sea level, or more than 310 feet above the bottom of the basin. Variation in elevation of the old beach from 30 to 57 feet above sea level indicates warping of the basin in recent time. In most places the old beach forms a sandy ridge or bench only a few feet high. West of Brawley this bench is half a mile wide, and 4 miles east of Niland, near the point where it is crossed by the railroad, it attains considerable prominence, and it continues in view to a point beyond Frink. Many fossil shells of fresh-water habit (including *Anodonta, Planorbis, Physa,* and *Tryonia*) occur in the sand. Near Fish Springs, on the south side of the basin opposite Salton siding, the old strand is marked by a band of white travertine, a fresh-water deposit of calcium carbonate, on the schists. This band is very conspicuous on a projection of the mountain known as Travertine Point (pl. 38, *B*) and encircling an isolated hill of granite 2 miles northwest of Fish Springs. The inundation of 1907 extended to the foot of the point, covering the old trail with more than 60 feet of water, but it fell far short of the ancient lake margin marked by the travertine. Macdougal [76] has estimated that the date of the last filling of Lake Cahuilla corresponding to the old beach was not more than 300 or 400 years ago. The local Indians have traditions of the lake which disappeared "poco á poco." Probably there were oscillations when freshets refilled it, a process which may have recurred at various times while the delta was being built.

Near the mouth of the Alamo River, on the southeast shore of the Salton Sea about 8 miles southwest of Niland, the presence of a center of volcanic activity is shown by ridges of lava pumice and active "volcanoes" of hot mud emitting sulphurous steam. One of these features is shown in Plate 38, *A*. There are other larger ones 75 miles farther south, near Volcano Lake, in Mexico. Pumice is

[74] This name applied to the former water body by W. P. Blake is that of the Indians who inhabited the valley and of whom about 200 remain living on several small reservations near Mecca, Cabazon, and Palm Springs.

[75] The name Coachella is probably a misspelling of "conchilla" (Spanish for little shell), which was used in the early days and printed on the earliest maps.

[76] Macdougal, D. T., A decade of the Salton Sea: Geog. Rev., vol. 3, pp. 457–473, 1917.

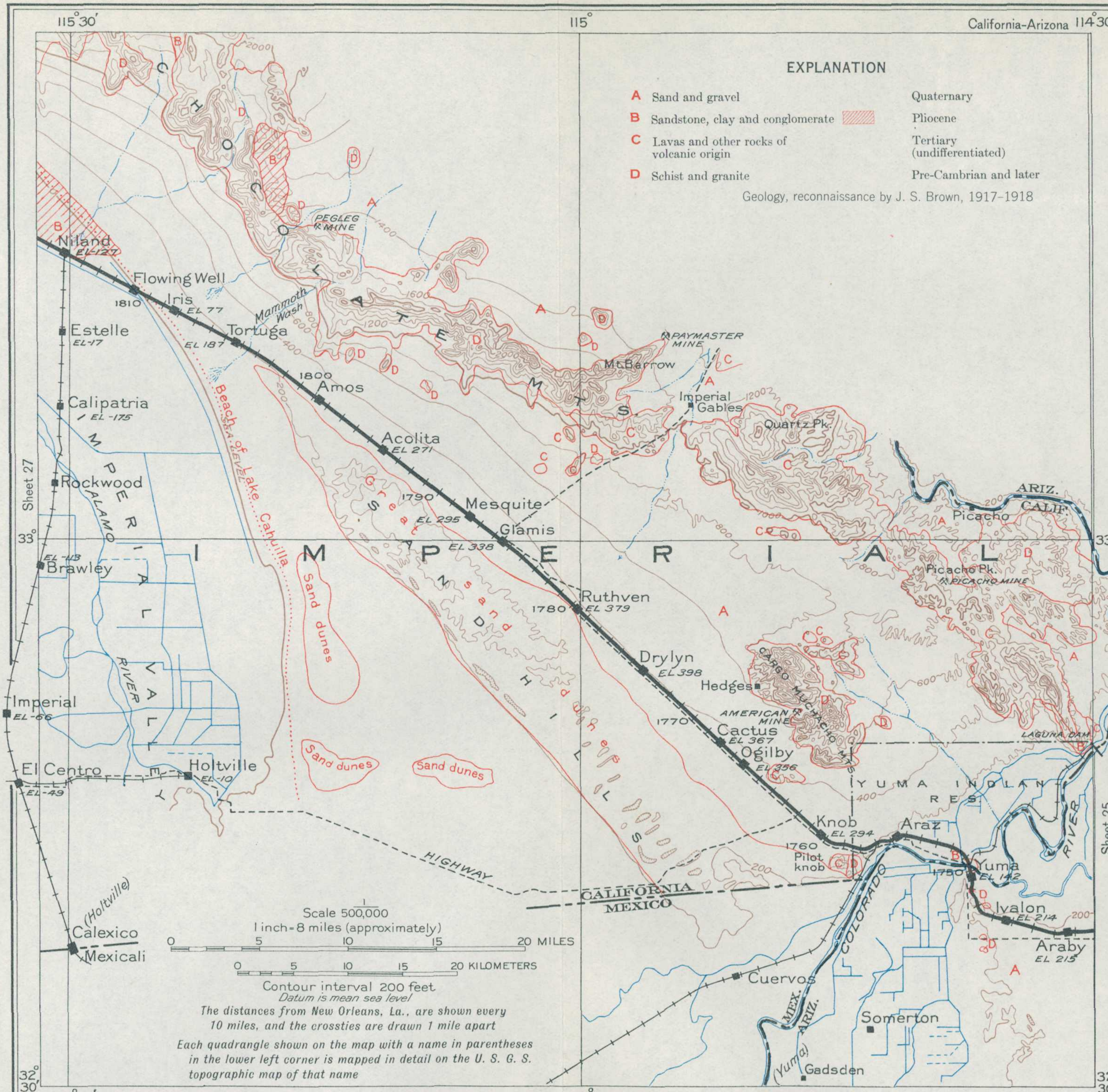
obtained at Obsidian Butte,[77] on the southeast shore of Salton Sea 11 miles northwest of Calipatria. It is interbedded with sediments and is the product of a volcanic eruption, probably from a cinder cone near the present mud volcanoes. The pumice is in pieces as large as 12 inches, and only those over 2 inches are shipped. The material is sorted by hand. There is another mine in a similar deposit 9 miles northwest of Calipatria, in an area of about 100 acres on a low rounded hill.

From Niland westward the mountains on the southwest side of the Colorado Desert or Salton Basin become conspicuous. To the southwest, across Imperial Valley, the Fish Creek and Superstition Mountains are clearly in view. Superstition Mountain consists of a ridge of gray biotite granite about 750 feet high, flanked on its north side by Tertiary sandstone and tuff with an interbedded flow of vesicular basalt about 200 feet thick. To the west are the rugged Santa Rosa Mountains, which consist of schists and granite; beyond this range rise the high San Jacinto Mountains, also made up of crystalline rocks. These ranges are sometimes known as the Peninsular Mountains because they continue far south down the great peninsula of Baja California. On the north side of the railroad west of Niland are low ridges of sandstone and shale of late Tertiary age which come to the surface at Niland. (Turn to sheet 27.)

At Mundo siding the Salton Sea is in sight (pl. 36, *B*), and the railroad skirts its north shore nearly to Mecca. It is a weird spectacle in the moonlight.

In crossing the Colorado Desert and Coachella Valley from Yuma to Banning striking changes will be noticed in the natural vegetation, especially near Banning, where the xerophilous ("drought-loving") Lower Sonoran flora ceases. Near Yuma the desert plants are about the same as those in Arizona, but the sahuaro is absent. The ocotillo (*Fouquieria splendens;* see pl. 41, *A*) occurs near the railroad as far west as a point a few miles beyond Glamis, where it recedes to the hillsides on the north, along which it continues to Red Canyon, near Mecca. The paloverde (*Cercidium torreyanum*) and indigo thorn (*Parosela spinosa*) continue to Palm Springs, and a few trees like the desert willow (*Chilopsis linearis*) and the mesquite (*Prosopis glandulosa*) extend part way through San Gorgonio Pass. The mesquite thrives in the sand dunes in the Indio and Indian Springs region, where a low trailing form (*Prosopis juliflora*) abounds. The beautiful Washington palm (*Neowashingtoniana filamentosa*) begins at the Dos Palmas Spring, north of Durmid, and occurs in groups at various springs along the mountain slopes past Indio.

[77] Rock from ledges in this butte has been found to be a rhyolitic obsidian, metamorphosed to a banded mixture of tridymite and barbierite, probably by the action of hot volcanic gases. (A. F. Rogers.)


California-Arizona
EXPLANATION
A Sand and gravel — Quaternary
B Sandstone, clay and conglomerate — Pliocene
C Lavas and other rocks of volcanic origin — Tertiary (undifferentiated)
D Schist and granite — Pre-Cambrian and later
Geology, reconnaissance by J. S. Brown, 1917-1918
CHOCOLATE MTS.
IMPERIAL
IMPERIAL VALLEY
Great Sand Hills
Niland
Flowing Well
Iris
Estelle
Tortuga
Calipatria
Amos
Acolita
Rockwood
Mesquite
Glamis
Brawley
Ruthven
Drylyn
Hedges
Cactus
Ogilby
Imperial
El Centro
Holtville
Knob
Araz
Pilot knob
Yuma
Ivalon
Araby
Calexico
Mexicali
Cuervos
Somerton
Gadsden
Picacho
Picacho Pk.
Quartz Pk.
Imperial Gables
Mt. Barrow
PAYMASTER MINE
PEGLEG MINE
AMERICAN MINE
PICACHO MINE
LAGUNA DAM
CARGO MUCHACHO MTS.
YUMA INDIAN RES.
Beach of Lake Cahuilla
Sand dunes
Mammoth Wash
ALAMO RIVER
COLORADO RIVER
HIGHWAY
CALIFORNIA
MEXICO
ARIZ.
CALIF.
MEX.
Sheet 27
Sheet 25
(Holtville)
(Yuma)
Scale 1/500,000
1 inch = 8 miles (approximately)
0 5 10 15 20 MILES
0 5 10 15 20 KILOMETERS
Contour interval 200 feet
Datum is mean sea level
The distances from New Orleans, La., are shown every 10 miles, and the crossties are drawn 1 mile apart
Each quadrangle shown on the map with a name in parentheses in the lower left corner is mapped in detail on the U. S. G. S. topographic map of that name

There are some groves of this picturesque tree in Palm Canyon, as shown in Plate 41, *B*. The creosote bush (*Covillea*) extends all the way up the valley, but in the more sandy places it is widely spaced and greatly stunted. It is the dominant plant near Garnet and Cabazon. The Spanish bayonet (*Yucca mohavensis*) continues west and is especially conspicuous near Cabazon. The cacti (mostly *Opuntia bigelovii*, *O. basilaris*, and *O. echinocarpa*) extend west along the mountain slopes but do not occur low in the basin, where apparently their altitudinal limit is passed. The ironwood (*Olneya tesota*) is widely distributed on the dry uplands and bears much mistletoe (*Phoradendron californicum*), a parasite which also infests the palo verde, mesquite, and other trees.

In the moist alkaline flats of the lower part of the valley the salt bushes (*Atriplex canescens* and *A. polycarpa*) and salt grass (*Distichlis spicata*) are the principal plants, and in wet places near springs rushes (*Juncus cooperi*), sedges or tules (*Scirpus olneyi*), arrowweed (*Pluchea sericea*), and willow (*Salix gooddingii*) flourish. The willow also forms dense thickets along the overflow lands bordering parts of the Colorado River.

The animals and birds in the desert region of southern California are the same as in southern Arizona and, except the coyote and rabbits, are rarely seen. Large animals occur in the mountains, and deer, sheep, and antelope are occasionally visible in out of the way places.

From Mundo siding to Mortmar siding the railroad is built largely on a bench near the shore of the Salton Sea. A short distance to the northeast of the tracks are hills and badlands of tilted sandstone and shale of Pliocene age. Some distance beyond rise the rugged slopes of the Chocolate and Orocopia Mountains.

At Frink siding is a crusher making "Frink rock" for concrete from detrital material consisting of boulders, mostly of schist, rhyolite, and andesite brought by freshet waters from the mountains. The capacity of the plant is 1,500 tons a day.

Bertram.
Elevation −189 feet.
New Orleans 1,835 miles.

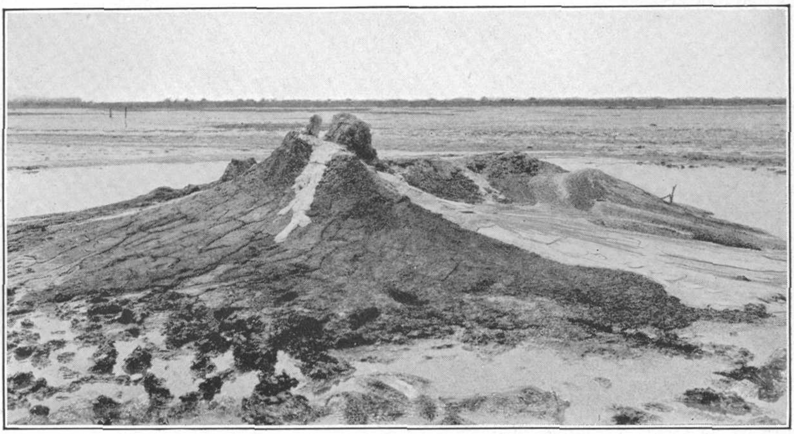
About 2½ miles northeast of Bertram siding are the "soda mines," where the mineral thenardite, an anhydrous sodium sulphate, with a small amount of the hydrous form (Glauber salts), has been quarried. The mineral occurs in a bed 3 inches to 8 feet thick in the Pliocene sandstones and clays, which here dip about 35° N. The clean mineral is more than 99 per cent pure, and the bed has been traced for 3,000 feet. Several thousand tons a year has been shipped to San Francisco for use in making wood pulp by the sulphite process and also in the manufacture of glass.

From Bertram siding to Mortmar the Orocopia Mountains are conspicuous to the north and northeast, culminating in a dark rounded peak about 3,000 feet high, which is visible for a long distance in the surrounding country. These mountains consist largely of old black schist, but according to Brown andesitic and rhyolitic lavas also occur in them. They are separated from the Chocolate Mountains, to the southeast, by the wide valley of Salton Creek. At their south foot, about 5 miles northeast of Salton siding, is Dos Palmas Spring (Spanish for two palms), a watering place on the old stage road from Ehrenberg to San Bernardino. The water, which is somewhat saline, rises in a marshy pool surrounded by rank vegetation, and on its bank is a small clump of Washington palms. A strip of loose sand marking the old shore of Lake Cahuilla is a notable feature 2 miles south of Dos Palmas Spring.

There are several notable springs along the southwest side of the Salton Basin, due to the escape of ground water under artesian pressure. They are marked by clumps of trees that can be seen across the valley from the railroad, although the distance is 15 miles. One is Kane Spring, nearly due south of Bertram siding. It yields a highly mineralized water rising from uptilted Tertiary strata. Another about 25 miles farther northwest, is Figtree John Spring, which yields good water. It received its name from an Indian who lived there for many years in a grove of fig trees. Near by is Fish Spring, nearly due south of Mecca, where warm water of poor quality forms a large pool and has a flow reported to be 280 gallons a minute. It is an outlet for the artesian flow from the higher part of the Coachella Valley. A small fish, *Cyprinodon californensis*, lives in the warm water. Near this spring the water line of old Lake Cahuilla (see p. 253) makes a well-marked horizontal band of light-colored travertine on the rocky slope near the base of the mountains and girdling an outlying hill.

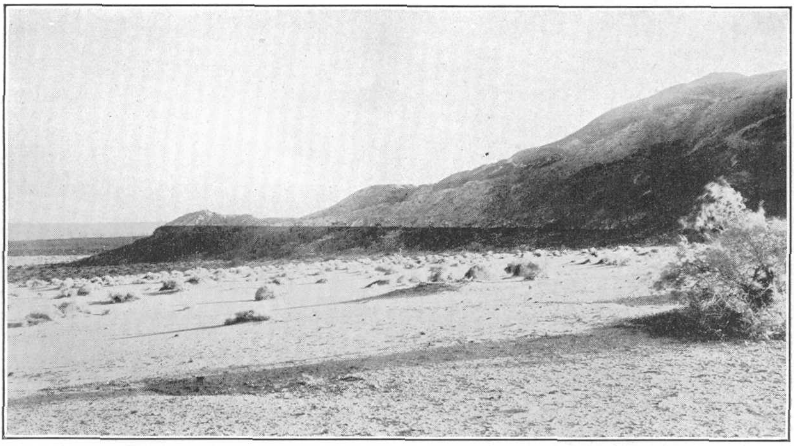
Near Mortmar siding the northwest end of the Salton Sea is passed, and in a few miles the route enters the Mecca irrigation district, where an area of considerable extent is irrigated by water pumped from wells of moderate depth.

Most of Coachella Valley is underlain by water-bearing sand and gravel, which in the area below sea level yield artesian flows to many wells. Some water is also raised by pumping. The wells are mostly about Mecca, Thermal, Coachella, and Indio, where the water is used extensively for irrigation. In fact, these places would be only passing sidings were it not for the underground water supply. The artesian water was discovered by the railroad company in 1888 at Thermal and Coachella, and since then 400 or more wells have been sunk, mostly from 500 to 600 feet deep and yielding from 10 to 40 miner's inches (90 to 360 gallons a minute), the amount depending on the size of the well and varying with the locality. The water is contained in sand in the valley fill, and the head is derived from the height of the intake on the sides and higher parts of the valley to the



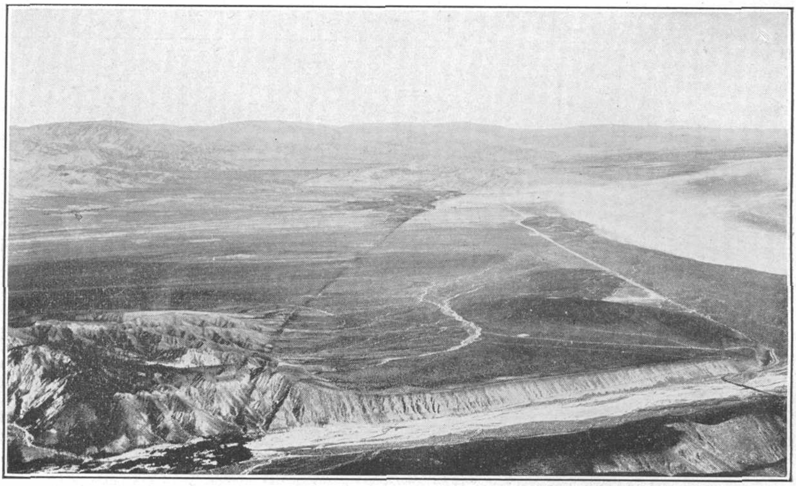
A. MUD VOLCANOES SOUTHWEST OF NILAND, CALIF.

Boiling mud probably heated by buried volcanic rocks. The water is believed to rise on the San Andreas fault.

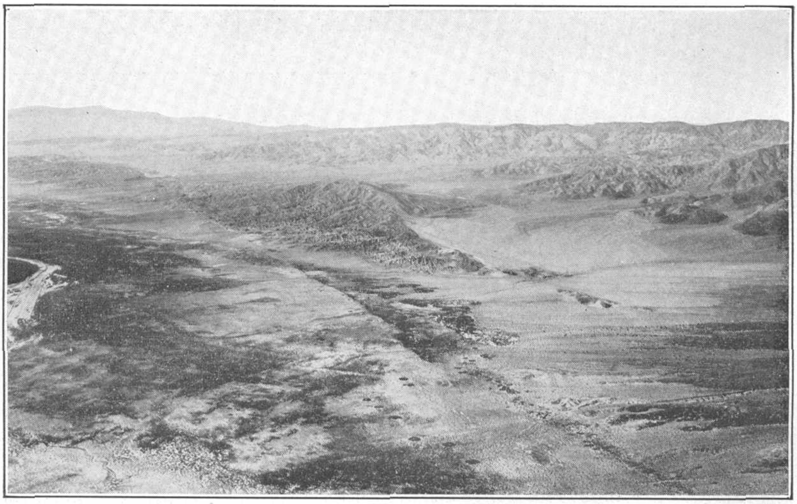


B. TRAVERTINE DEPOSIT MARKING STRAND OF ANCIENT LAKE CAHUILLA NEAR FIGTREE JOHN SPRING, ON SOUTH SIDE OF SALTON BASIN, CALIF.

Santa Rosa Mountains at right. (Mendenhall.)



A. VIEW SOUTHEAST FROM A POINT 3 MILES NORTH OF BANNING

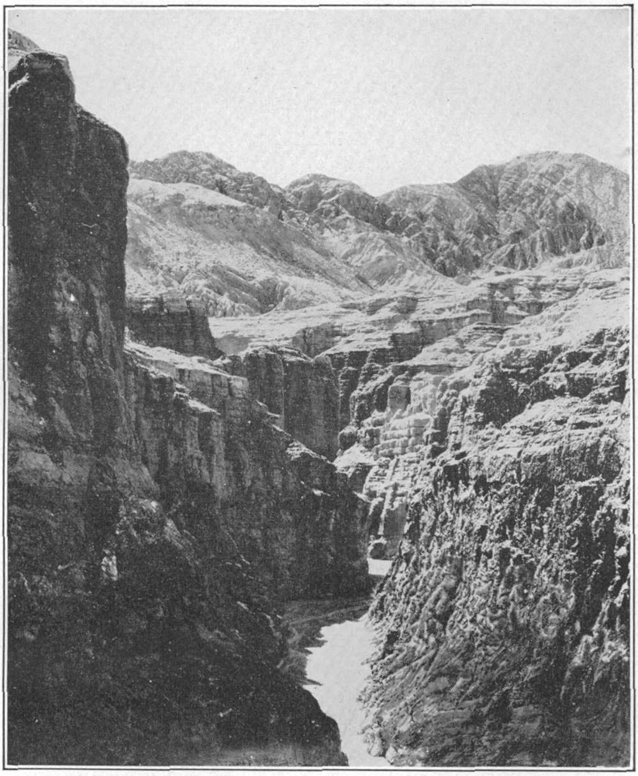


B. VIEW NORTHWEST FROM A POINT 2 MILES NORTH-NORTHEAST OF INDIO

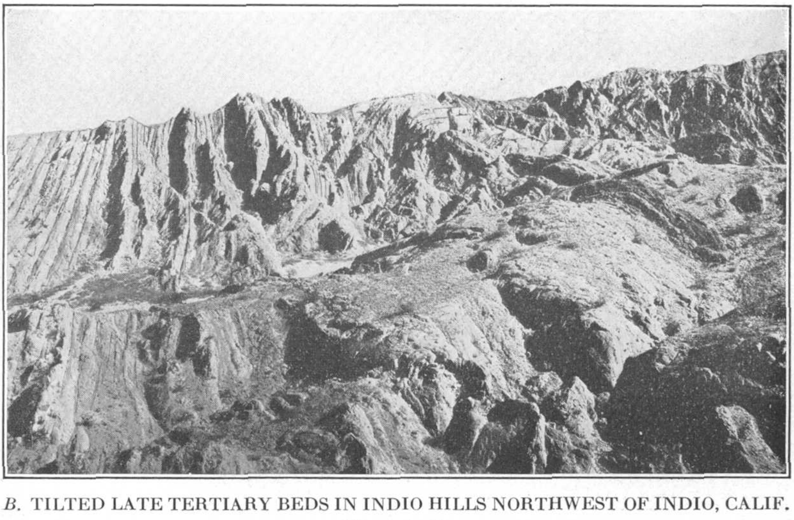
Little San Bernardino Mountains in distance.

SAN ANDREAS FAULT NEAR BANNING AND INDIO, CALIF.

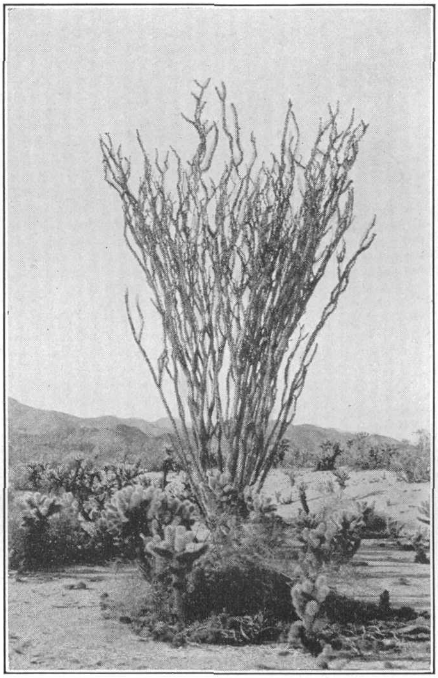
(Continental Air Map Co.)



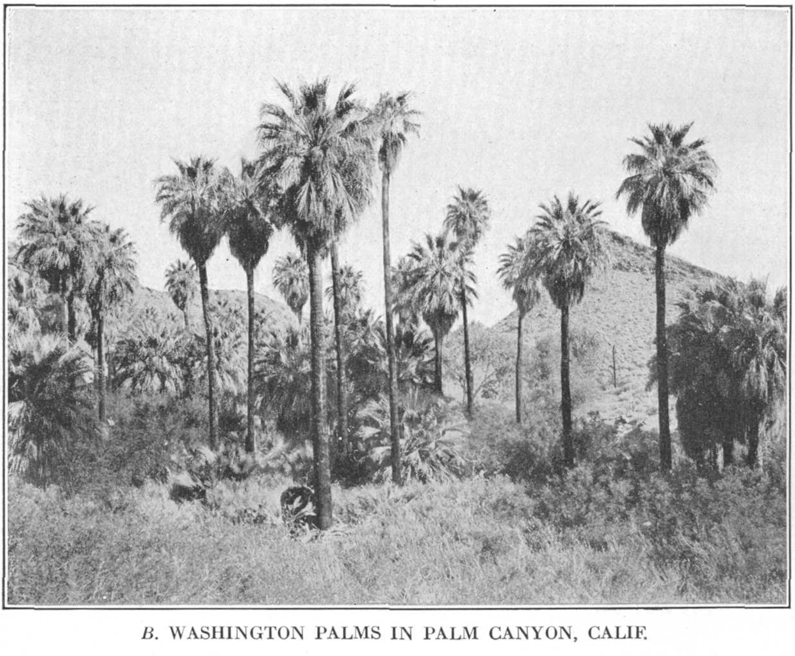
A. CANYON IN TERTIARY STRATA EAST OF MECCA, CALIF.



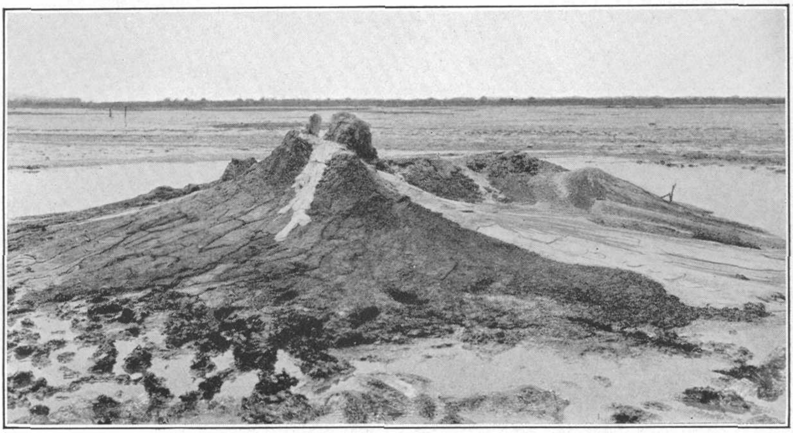
B. TILTED LATE TERTIARY BEDS IN INDIO HILLS NORTHWEST OF INDIO, CALIF.
(Mendenhall.)



A. OCOTILLO AND CHOLLA, COACHELLA VALLEY, CALIF.

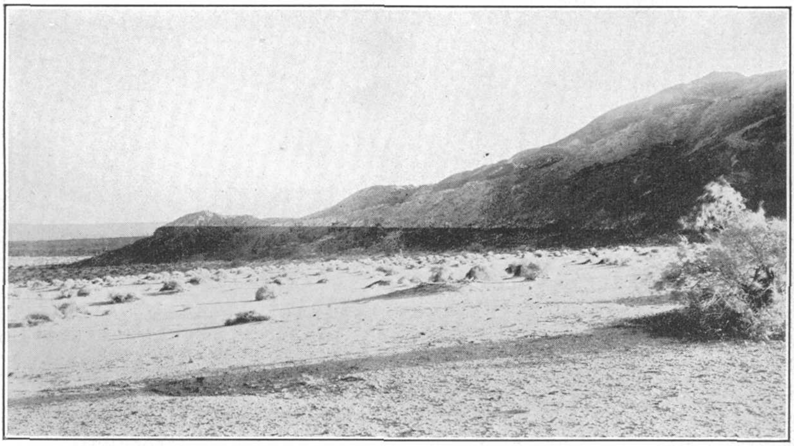


B. WASHINGTON PALMS IN PALM CANYON, CALIF.



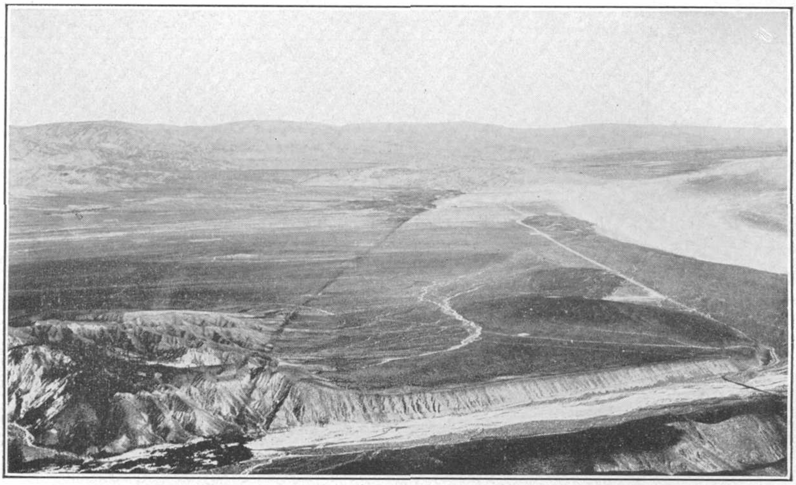
A. MUD VOLCANOES SOUTHWEST OF NILAND, CALIF.

Boiling mud probably heated by buried volcanic rocks. The water is believed to rise on the San Andreas fault.

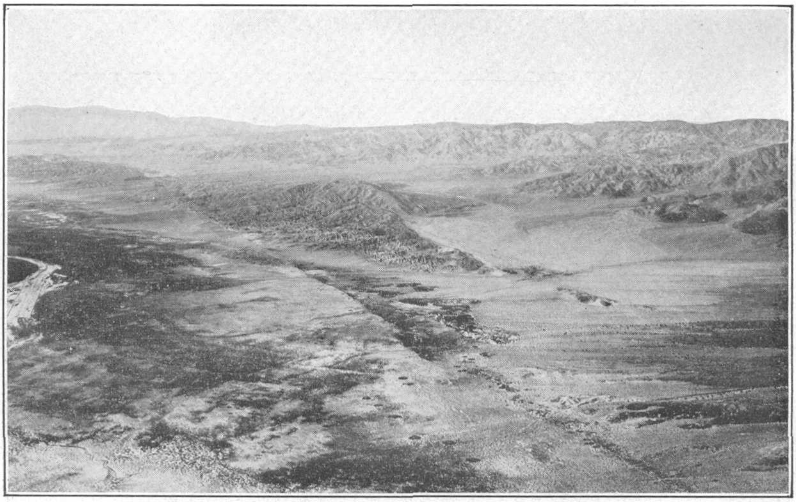


B. TRAVERTINE DEPOSIT MARKING STRAND OF ANCIENT LAKE CAHUILLA NEAR FIGTREE JOHN SPRING, ON SOUTH SIDE OF SALTON BASIN, CALIF.

Santa Rosa Mountains at right. (Mendenhall.)



A. VIEW SOUTHEAST FROM A POINT 3 MILES NORTH OF BANNING

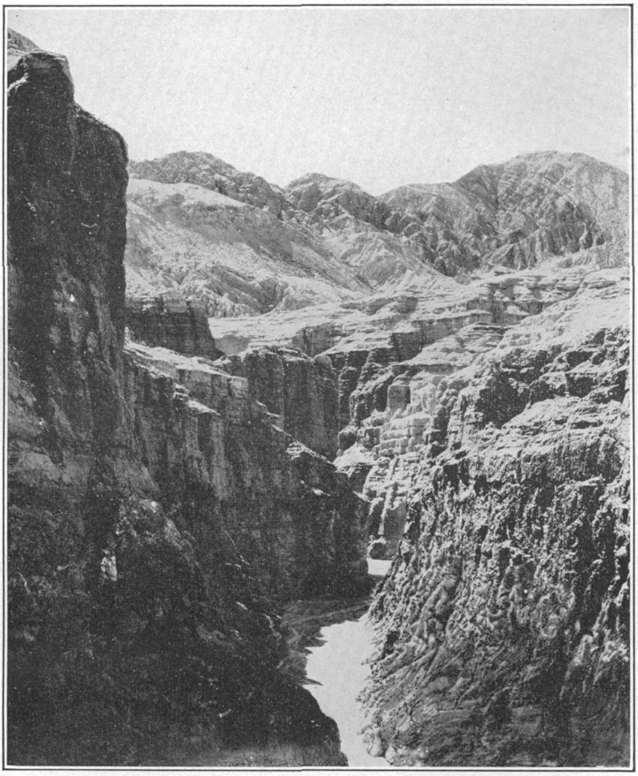


B. VIEW NORTHWEST FROM A POINT 2 MILES NORTH-NORTHEAST OF INDIO

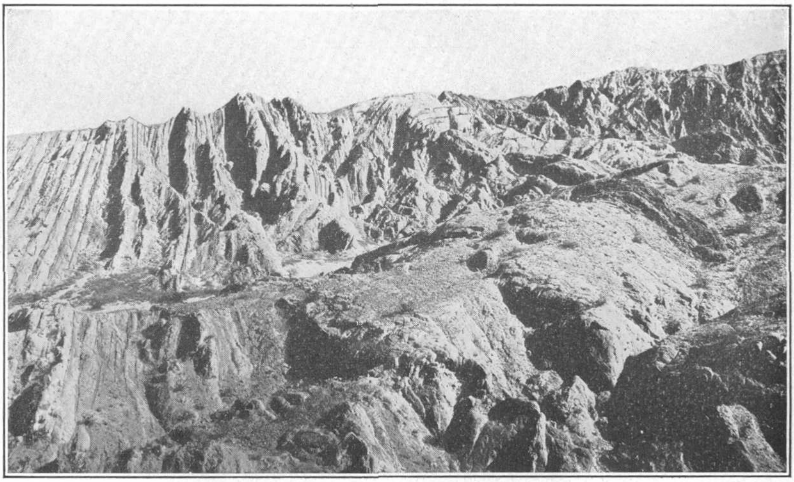
Little San Bernardino Mountains in distance.

SAN ANDREAS FAULT NEAR BANNING AND INDIO, CALIF.

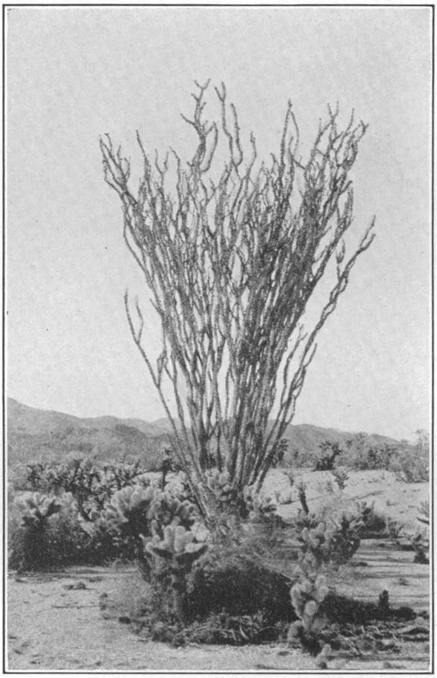
(Continental Air Map Co.)



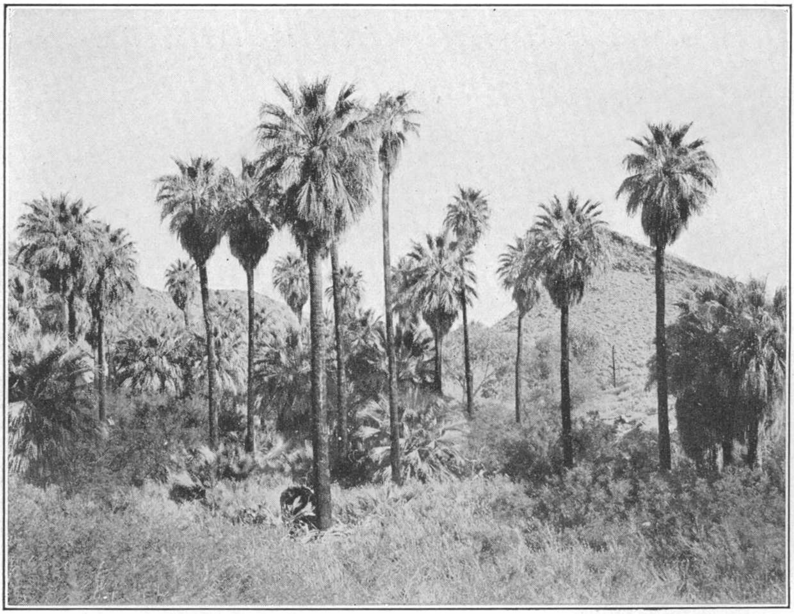
A. CANYON IN TERTIARY STRATA EAST OF MECCA, CALIF.



B. TILTED LATE TERTIARY BEDS IN INDIO HILLS NORTHWEST OF INDIO, CALIF.
(Mendenhall.)



A. OCOTILLO AND CHOLLA, COACHELLA VALLEY, CALIF.



B. WASHINGTON PALMS IN PALM CANYON, CALIF.

north and is maintained by the impervious cover of fine-grained deposits which occupy the center of the basin. The water is derived from rainfall on the mountains and higher slopes, which passes underground in the coarse material extending as alluvial fans along the foot of the mountains. Most of the water falling on the mountains runs off the hard rocks and steep slopes but is absorbed by the gravel and sand of the valley fill. Several streams, such as Whitewater Creek, Snow Creek, Tahquitz Creek, Andreas Creek, and the creek in Palm Canyon, sink in that way. In the northern portion of the valley the underground water is of excellent quality, containing only from 150 to 250 parts per million of mineral constituents, but south of a line from the south end of the Santa Rosa Mountains to Salton siding the waters are too saline for use.

The underground water supply about Indio and southward to Mecca is limited in amount, but about 16,000 acres is being irrigated. The crops include melons, dates, grapes, alfalfa, and many other products. The United States Department of Agriculture has made a detailed study of the soils of the Indio area, and many experiments have been made to determine the best crops and proper conditions for their irrigation. Underground waters are pumped at several places west of Indio for irrigation and other purposes. Water furnished by springs and wells east of Salton siding is of too poor quality for irrigation.

At Mecca (formerly called Walters) the Coachella Valley is a wide alluvial flat extending from the foot of the Santa Rosa Mountains on the southwest to the Mecca Hills on the northeast. The Mecca Hills consist of a 5,000-foot succession of steeply tilted yellowish sandstone and sandy shales with a basal member 1,000 to 1,200 feet thick of brownish-red sandstones and conglomerates. These rocks are well exposed on the Shaver Canyon road east of Mecca. (See also p. 259 and pl. 40, *A*.) The strata are closely folded, as shown in Figure 62. In Burnt Springs Canyon and near Hidden Spring, east of Mecca, the anticlinal structure of the front ridge is well shown. At Hidden Spring the sedimentary rocks appear to be invaded by a mass of rhyolite. At Shaver Well, about 10 miles east of Mecca, a mass of old schist is exposed in contact with the overlying conglomerate and sandstone. To the east of this place are the high ridges of dark schist known as the Orocopia Mountains. A sandy strip marking the old beach of former Lake Cahuilla is crossed by the highway a few miles east of Mecca, before it enters Shaver Canyon.

Mecca.

Elevation −188 feet.
Population 800.*
New Orleans 1,859 miles.

About Mecca the principal products of irrigation are oranges, dates, and Bermuda onions, which are shipped to all parts of the United States.

Many date palms are growing in the vicinity of Mecca and Indio, where the climate and soil seem particularly favorable. Experimental work on date culture was begun in this area by the United States Department of Agriculture in 1904, utilizing waters pumped from wells. Tests were made of many varieties from the principal date-growing regions of the Old World, but only a few were found to be suitable. The annual rainfall is less than 3 inches, and the humidity is very low. Although the temperature is high for most of the year, it falls below 32° at times, and it has gone to 15°. In midwinter there are light frosts, which seldom continue beyond February. Most varieties of dates are injured by the slightest rainfall or even by dew during the ripening season, so that the complete dryness generally prevailing from August to November is especially favorable to the maturing of the fruit. As the soil at Mecca is nearly pure sand on the old lake beach, care has to be taken to develop sufficient humus and prevent the too rapid sinking of the irrigation water. There is more silt in the soil at Indio. It is necessary also to protect offshoots and seedlings in canvas-covered sheds where suitable temperature and humidity can be maintained. Most dates designed for long keeping and export have to be picked before they are fully ripened and care-

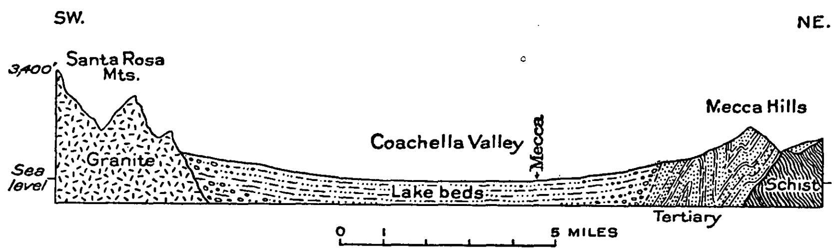


FIGURE 62.—Diagrammatic section across Coachella Valley through Mecca, Calif. By W. C. Mendenhall

fully sun dried. Seedling dates are about half females, which alone bear fruit, so that all males in excess of those necessary for pollination are culled out as soon as they can be recognized, which is from the age of 3 to 4 years. Pollination is best accomplished by shaking a frond of male flowers over the female flowers or by tying them together so that the wind will transfer the pollen. Trees usually bear fruit in four years, at first in small amounts and then increasing in size and productiveness for many years. The fruit hangs in great clusters, as shown in Plate 37, *A*, and ripens in September, October, or November. On the 40-acre experimental date farm of the United States Department of Agriculture, about a mile southeast of Mecca, systematic tests are in progress on the culture not only of dates but of other fruits suitable to the region.

At Mecca the railroad company has a 1,500-foot well which supplies 400 gallons a minute of water of excellent quality, used for locomotives at various places between that place and Glamis. The first well here, bored by the railroad company in 1894, struck an artesian flow similar to that found at Thermal and Coachella several years before.

Thermal is a village in the irrigation settlement that extends along the Coachella Valley from Mecca to Indio and beyond. The fine fields of alfalfa and other products of irrigation in this area contrast strongly with the desert conditions in the valley lands which have not been reclaimed. The soil is rich and responds readily to cultivation, and many oranges, dates, and melons are grown, irrigated by water from wells.

Thermal.

Elevation −121 feet.
Population 400.*
New Orleans 1,865 miles.

In ascending the Coachella Valley there are fine views of the adjoining mountains. To the west is the Santa Rosa Range, consisting mainly of hard schists and igneous rocks. To the east are the low but rugged Mecca Hills, consisting mostly of softer sandstones and clays. These and the Indio Hills, their northwesterly continuation, rise about 1,000 feet above the valley plain and show a large amount of badland topography due to rapid erosion cutting steep-sided gullies in soft materials. There are two distinct formations. The lower one, of marine origin and regarded as the same as the late Tertiary beds in the Carrizo Mountains, far to the southeast, crops out in small areas east and west of the mouth of Thousand Palms Canyon and in the northern part of the Indio Hills. It consists of yellow clay with some sandstone and conglomerate and indicates an extension of the waters of the Gulf of California to San Gorgonio Pass in late Tertiary time. In places it carries reefs filled with fossil oysters. It is overlain by several thousand feet of late Tertiary clays, apparently playa deposits, arkosic sandstones, and conglomerates. (Woodring.) [78]

Coachella.

Elevation −66 feet.
Population 700.*
New Orleans 1,869 miles.

The strata in the Indio and Mecca Hills are folded in compressed anticlines and synclines, which in general are parallel to the trend of the hills, but the strike is somewhat more to the north and the beds are cut off diagonally by the San Andreas fault, which passes along their south side,[79] as shown on sheet 27.[80]

[78] At the base of the Tertiary in this region is a conglomerate which at most places near the contact includes many fragments of the underlying schists. The material becomes finer grained farther away from the contact, the conglomerate grading laterally into sand and clay. This gradation is well exhibited in Shaver Canyon, east of Mecca, where near Shaver Well the conglomerate becomes coarser. The sand is mostly an arkosic mixture of quartz and feldspar fragments with more or less mica, all derived from near-by ledges of older rocks. (Brown.)

[79] Noble, L. F., personal communication.

[80] At the entrance to Shaver Canyon the beds of soft sandstone and clay dip about 15° SE. The rate of dip increases rapidly, and within half a mile the strata are vertical or slightly overturned in a crushed anticline, as shown in Plate 40, *B*. Northeast of the axis the dip is to the northeast, and here the anticline is overturned, with vertical dips on its northeast side. This general anticline has been traced southeastward for several miles. East of this anticline there is a broad basin, on

The San Andreas fault is a break in the earth's crust that extends for many miles across southern and central California. Movement along it began far back in the Tertiary period and has progressed at intervals to very recent time.[81] It passes along the southwest side of the Mecca and Indio Hills and traverses the valley-fill deposits in the intervals between these ridges, where in places it gives rise to a low cliff. This feature is well shown in the airplane photograph reproduced in Plate 39. Its course, as recently determined by L. F. Noble, is shown on sheets 27 and 28, together with that of another similar break known as the Mission Creek fault, which joins it near Indio.

The fault trace is less conspicuous along the south side of the Mecca Hills, where in places it is marked by a low bluff, extending as far as Mortmar siding. It is believed by Noble to continue southeastward under the Salton Sea to the mud volcanoes southwest of Niland and thence southeastward by Brawley and Holtville. Another fault beginning in the Indio Hills is believed to extend through Dos Palmas and Frink Springs and continue approximately parallel to the railroad northeast of the sand-hill belt. There are scarps and springs in places along its course.

North of Indio the fault extends along the southwest margin of the Indio Hills nearly parallel to the railroad and from 2 to 3 miles distant.

The older crystalline rocks of the high mountains bordering the Colorado Desert and Coachella Valley are schists and gneisses penetrated by old granite. These schists and granites are cut by younger granitic igneous masses and overlain by a younger series of schists, limestones, and quartzites that are considerably metamorphosed. (Brown, Vaughan, and Frazer.)

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the east side of which basal conglomerates rise on the mass of schist that appears at Shaver Well. (Brown.)

The Indio Hills have practically the same structure as the Mecca Hills, except that they consist mainly of two anticlines in a faulted block cut off on the southwest by the San Andreas fault. (Noble, L. F., personal communication.)

[81] That there still is movement along this fault or other faults west of it from time to time is probably indicated by earthquakes in Imperial Valley. One occurred at Brawley March 1, 1930, and another in 1932, and others are recorded at other points at times in Coachella Valley. (See also Beal, C. H., Seismol. Soc. America Bull., vol. 5, pp. 130–148, 1916.) In order to determine the amount of vertical movement on this line of displacement precise levels have been run across this region by the United States Coast and Geodetic Survey through El Centro, Niland, Yuma, and Jacumba, a distance of 158 miles. These, when compared with previous levels, indicate slight vertical displacement a short distance south of Niland (probably on an extension of San Andreas fault), just south of Brawley, and farther south on the supposed eastward continuation of the Elsinore fault. The earthquake of March, 1932, which caused much loss of life and destruction near Long Beach, was due to movement that centered in the ocean, to the west.

About Indio are many trees and fields of alfalfa and various other crops. A large date orchard can be seen just north of the railroad west of Indio, and in the station yard is a fine Deglet Noor date palm (female), imported from North Africa, "the offshoots of which are always true to type." At Indio is the winter resort of the Los Angeles Y. M. C. A., and near by is the attractive resort of La Quinta (keen'ta).

Indio.

Elevation −15 feet.
Population 1,500.*
New Orleans 1,872 miles.

The tilted Tertiary rocks constitute the range of high ridges known as the Indio Hills, which lie about 5 miles northeast of Indio.

In the center of the valley west of Indio and north of Indian Well is a heavy accumulation of dune sand, some of it bearing considerable stunted mesquite. Loose sand is an abundant material in the Coachella Valley, most of it shifted by strong winds that separate the sand from the coarser materials brought into the basin by many side streams. Small sand dunes accumulate, but the material is moved rapidly. The wind-blown sand is a powerful agent of erosion, cutting rocks, metals, and wood; the railroad company finds that the replacement of railroad equipment, telegraph poles, and bridge timbers is a considerable item of expense. It will be noted that many of the telegraph poles are protected by a pile of stones at their base. Sand storms occur occasionally, and if the traveler is not protected he may find them trying. The sand is rounded and worn as it cuts and finally loses most of its abrasive quality. Pebble pavements seen in many desert regions look almost artificial. They owe their origin largely to the removal of sand by the wind so that the pebbles remaining settle down into a pavement that resists further erosion. The surfaces of the pebbles are smoothed and polished by the attrition of sand carried by the wind.[82]

From Indio northwestward the railroad ascends the Coachella Valley through Myoma, Dry Camp, and Edom sidings. At Edom there is a small irrigated area in which some of the fields are surrounded by tamarisk. This tree was imported from southern Europe, for use in making hedges and windbreaks. As it withstands droughts and thrives under various other adverse conditions, it has proved very useful in the Southwest. As it is not an evergreen and is quite unlike cedar or juniper, the name "salt cedar," by which it is often known, is

[82] Some kinds of igneous rocks and sandstones in desert regions show pitted or cavernous surfaces, with cavities of various sizes up to several inches in diameter, differing materially from the grooving and fluting caused by wind-blown sand. These cavites are believed to be due to inequalities in rock disintegration by solution of the cement or of certain minerals that hold the grains together. Wind and other agencies remove the disintegrated material. The same process has much to do with the isolation and sculpturing of odd-shaped rocks in the desert region. (Blackwelder.)

inappropriate. A wide area of sand occupies the valley from a point beyond Indio to Myoma. To the north are prominent hills of sandstone of late Tertiary age, in front of which passes the San Andreas fault. This fault cuts the sandstone for a short distance near the west end of the range. At intervals along the San Andreas fault and sustained by moisture which it brings to the surface, are small clumps of the Washington palm, mostly visible from the train. Behind the hills about 6 miles northeast of Edom are the Thousand Palm Springs (pl. 41, *B*), the water of which is believed to rise on the Mission Creek fault. Farther back are the high ridges of the Little San Bernardino Mountains, which consist of a great batholithic mass of granitic rock ranging from pink biotite granite to dark diorite. (Brown.)

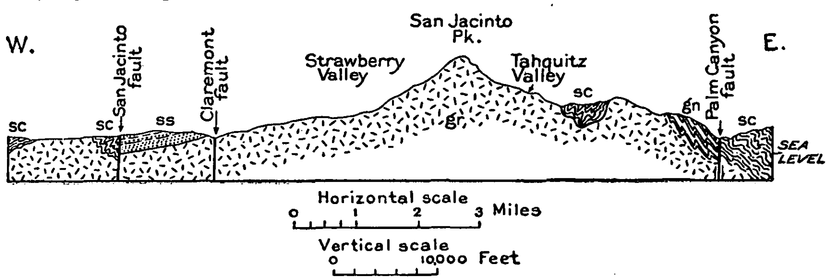


FIGURE 63.—Section through the San Jacinto Mountains, Calif. After Frazer. ss, Sandstone; sc, schist; gn, gneiss; gr, granite

The San Jacinto Mountains, prominently in view to the northwest (pl. 42, *A*), consist of a huge central mass of granite [83] flanked by schistose rocks [84] believed to be a contact phase of the granite. (See fig. 63.)

Rimlon.

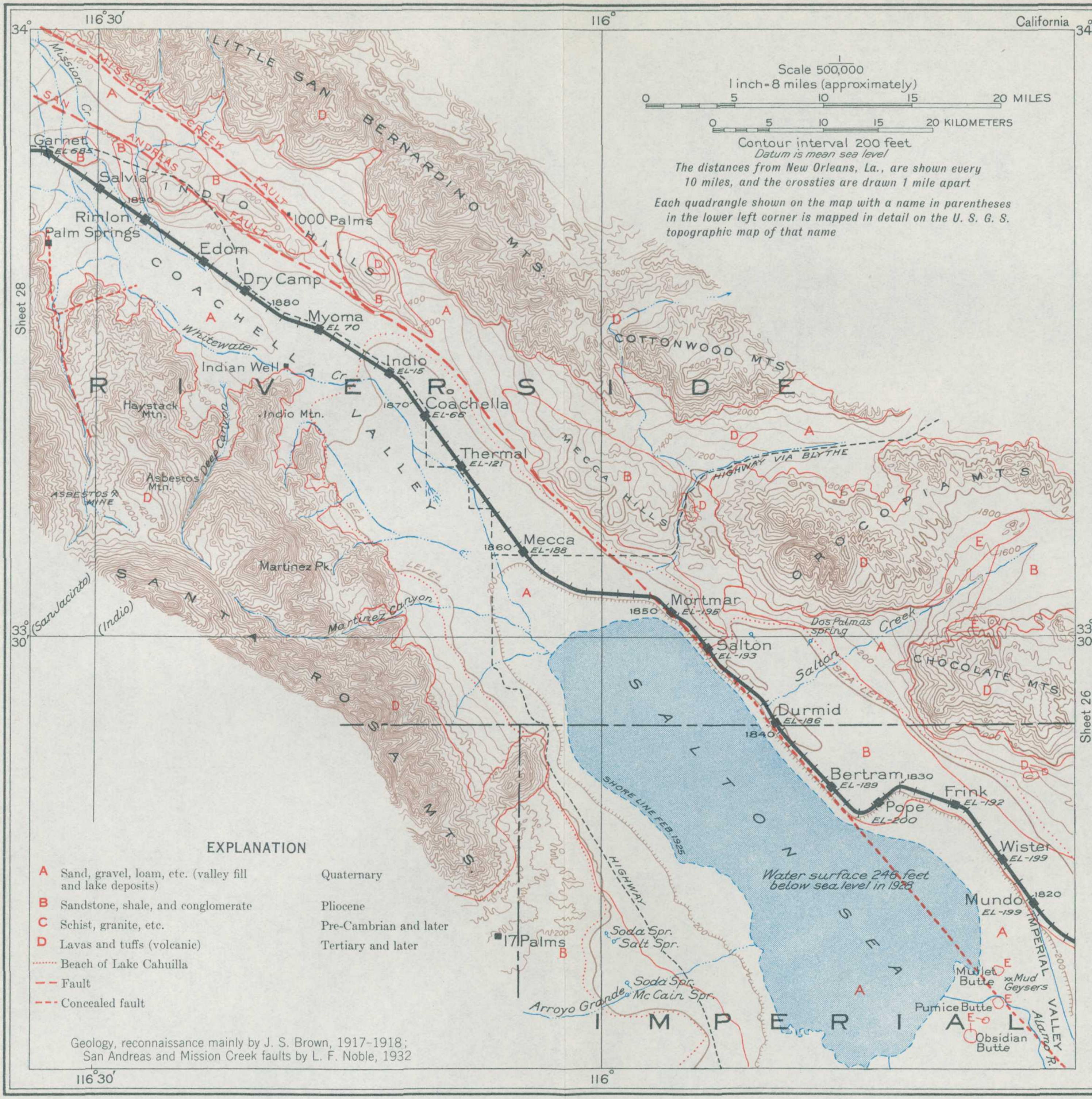
Elevation 400 feet. New Orleans 1,888 miles.

At Rimlon siding the railroad skirts a large hill of loose conglomerate, mostly covered with white wind-blown sand in which Woodring has found marine Tertiary fossils. These fossils also were found in and near Painted Hill, a ridge east of the Whitewater River not far north of the railroad. There are numerous mollusks in large variety and many Foraminifera.

The Whitewater River is a wide dry wash filled with boulders and sand. It is a flowing stream in the mountains just north of the rail-

[83] According to Frazer, the granite mass of the San Jacinto Mountains is mostly a massive light-gray nonporphyritic rock, consisting mainly of orthoclase, microcline, plagioclase, quartz, and biotite, these minerals varying somewhat in proportion and size from place to place. Under the microscope it is seen that the grains are generally fractured but without displacement. The mica constitutes from 8 to 10 per cent and the feldspars 60 to 70 per cent. Some of the rock would be classed as quartz monzonite, granodiorite, and quartz diorite.

[84] The schists dip away from the central mass at angles mostly from 30° to 60° and in places are overlain by younger schists, 2,600 feet or more thick and varying somewhat in mineralogic character. The younger schists include a small amount of intercalated limestone (marble). These rocks are believed to have been metamorphosed



Topography south of railroad by U. S. Geological Survey; north of railroad by Los Angeles Dept. of Water and Power

WILLIAMS & HEINTZ CO., WASH., D. C.

road, but the water sinks rapidly when it reaches the valley fill. In times of flood, however, it runs far down the Coachella Valley and has been known to reach Salton Sea. (Turn to sheet 28.)

Palm Springs Station is 7 miles northwest of Palm Springs, a popular winter resort in the valley that separates the Santa Rosa Mountains from the San Jacinto Range. The village is of considerable size and has many luxurious homes and hotels. The springs issue from the valley fill, probably rising on a fault fissure in rocks below this deposit, as the tepid water indicates a deep-seated source. The water has a very low mineral content (243 parts per million), mostly sulphates and chlorides of sodium and potassium, silica, and a small amount of sulphureted hydrogen, which soon passes off. The flow, estimated by Brown at about 10 gallons a minute, makes a pool some 60 feet in diameter.

Palm Springs Station.
Elevation 1,130 feet.
New Orleans 1,901 miles.

These springs belong to "Mission" Indians, who live on several small reservations in the valley. These people are of the Yuman family, now greatly diminished in number. At a place about 1 mile north of Coachella siding the United States Government has a small pumping plant to supply well water for irrigation on the Cabazon Indian Reservation.

The San Jacinto Mountains present steep slopes, especially to the northeast, Snow Creek, for example, dropping 4,000 feet in 1 mile of its course, and many other deep canyons head in this slope. The southwest side of this range is less steep and is bounded by the San Jacinto fault, movement on which in 1899 and 1918 caused serious earthquakes in San Jacinto and Hemet. The east side of the range is also very precipitous, for at Palm Springs, which is at an elevation of 455 feet, steep slopes rise more than 10,000 feet to the summit, San Jacinto Peak, as shown in Plate 42, *A*. This steep front is largely due to a great fault trending north, which is clearly exposed just west of Palm Springs Station. Here the mountain face consists of granite and gray marble in layers that dip 75° or more to the northeast, and a prospector's tunnel shows a fault breccia with slickensides. This

long before the granite was intruded, which may have been in late Jurassic time. The antiquity of their metamorphism is indicated by the fact that they are crystalline far away from the granite contact. Their age may be early Paleozoic, as they resemble rocks of that age in the region to the north. Although the great central mass of granite is massive, there is a marginal phase which is so schistose as to be classed as granite gneiss, a rock extensively exposed on the west side of Palm Canyon and in the region about Andreas Canyon. Its thickness may be 4,000 feet. The intrusive nature of the granite is proved by the contact relation and by the presence of included masses of schist (xenoliths) and limestone. The contact line is very irregular. (Frazer.)

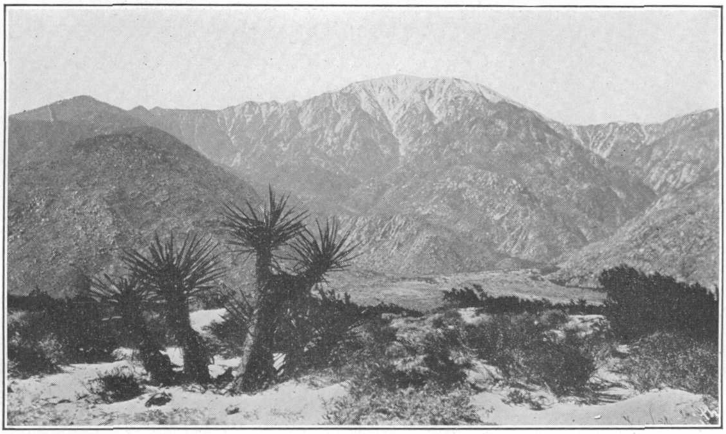
fault probably passes under the settlement at Palm Springs, for it is well exposed a few miles south of that place, where the planes of movement are marked by wide bands of crushed and strongly weathered rock. There are springs along this broken zone, and also tufa deposits 20 feet thick covering several acres, marking the position of ancient springs. Apparently this fault is now quiescent. There are several branch and cross faults in the Murray Hill district, on the east side of the valley about 5 miles southeast of Palm Springs. (Frazer.)

Above Palm Springs Station the Coachella Valley becomes narrower as it rises into San Gorgonio Pass, which separates the San Jacinto Mountains on the south from the San Bernardino Mountains on the north. The principal narrowing takes place near the mouth of Whitewater Canyon, on the west side of a north-south fault on which a block of the old hard rocks is uplifted. Above this fault the side slopes become steeper, notably on the south side of the valley, where they rise 9,500 feet to San Jacinto Peak. On the north side there is a rise of about 6,000 feet to the crest of a high outlying ridge on the south slope of the San Bernardino Mountains. This gives a steep-sided profile, but the valley bottom appears nearly flat in cross section, and its center is occupied by wide, boulder-filled washes containing material moved by the occasional freshets.

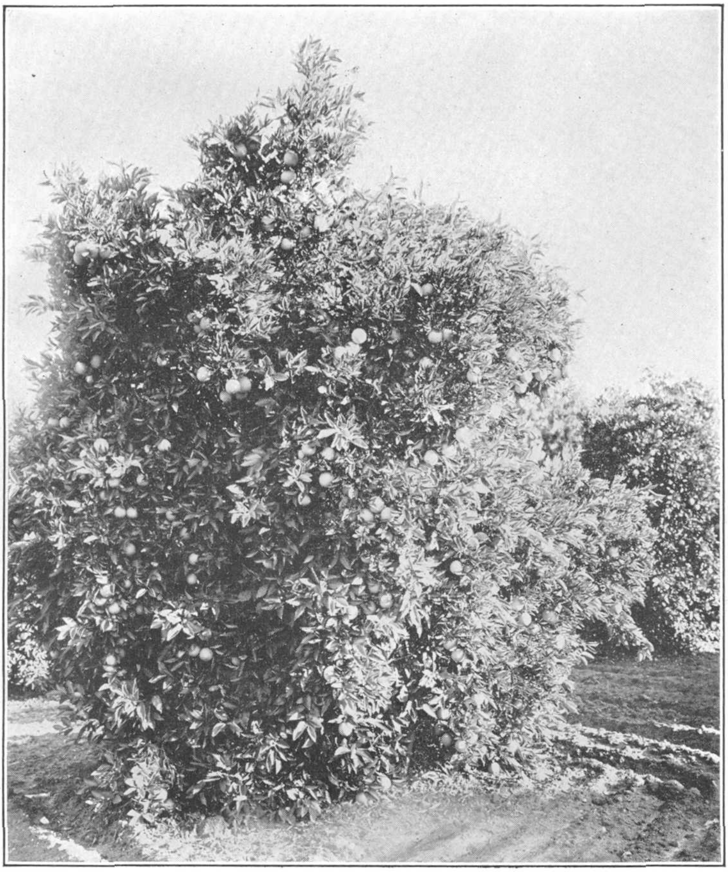
The streams flowing out of the mountains are building alluvial fans of large size, one of the most conspicuous of which is at the mouth of Snow Creek Canyon, south of Fingal siding, not far beyond Palm Springs Station.

San Gorgonio Pass is a dropped block of the earth's surface carrying an extensive body of recent sediments and lying between two great ranges of crystalline rocks. It is from 2 to 3 miles wide, and it extends almost due east and west for about 18 miles in the ordinary application of the name. To the east it merges into the Coachella Valley and to the west near Beaumont into the wide Beaumont Plain. Many of its relations have been discussed in detail by Russell, who regards the south wall as a fault scarp which has been moderately active in recent time, but the northern side is probably an old denuded thrust block face. The sediments at the margin of the pass were deposited under conditions somewhat similar to those now prevailing.

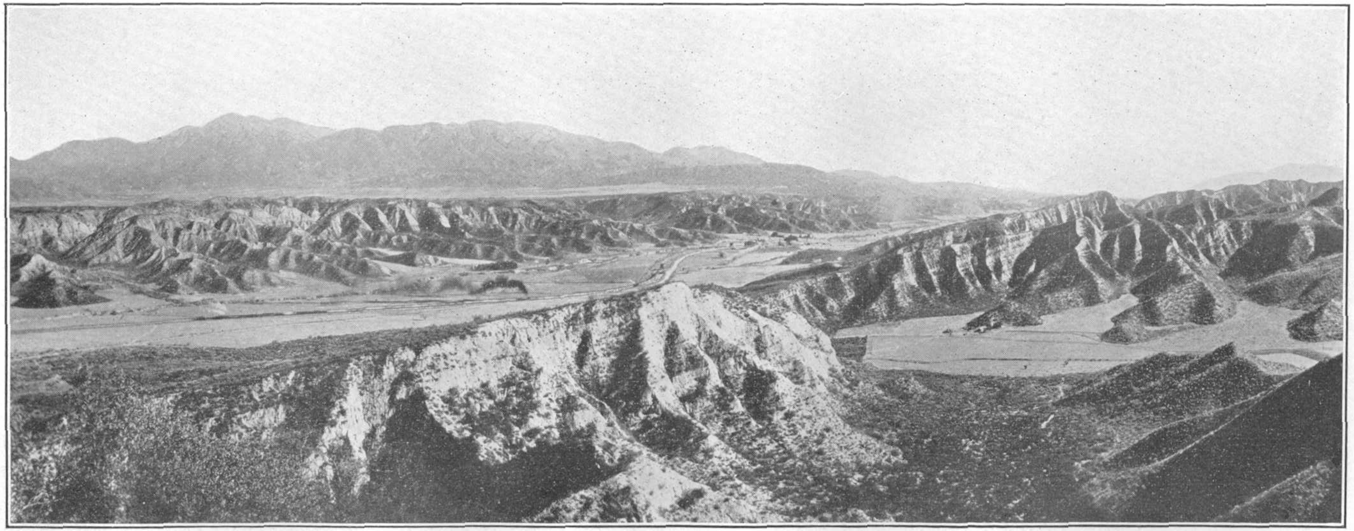
In 1800 to 1850 many American explorers, mostly hunters, came into the lower Colorado River region. It is stated that in the gold rush of 1849–50, 10,000 people crossed the Colorado River at Yuma. The earliest trail ran from Yuma, passing south of the southeast end of the sand hills through Mexico, thence along the Alamo River, across the present Imperial Valley, up the valleys of Carrizo and San Felipe Creeks, and over Warners Pass behind the Santa Rosa and San Jacinto Mountains to the coast. It was along this route in 1848 that Lieut. W. H. Emory led a military reconnaissance, and in 1857 it was used



A. SAN JACINTO MOUNTAIN, CALIF., FROM THE EAST SIDE OF COACHELLA VALLEY



B. ORANGE TREES IN FRUIT, REDLANDS, CALIF.



VIEW EAST UP SAN TIMOTEO CANYON AND ACROSS YUCAIPE BASIN FROM A POINT 1 MILE SOUTH OF REDLANDS, CALIF.

Tilted late Tertiary strata at right; San Bernardino Mountains at left. (Mendenhall.)

by the stage line to San Diego and by the Butterfield stage line the following year. San Gorgonio Pass was discovered in 1774 by Padre Francisco Garcés, who went through it on the way to Mission San Gabriel and named it Puerto de San Carlos. It was traversed again in 1775 by Juan Bautista de Anza on his expedition to found San Francisco. The first American exploration was made in 1853 by a party under Lieut. J. G. Parke, of the United States Engineers, with W. P. Blake as geologist, members of the expedition sent out to discover a route for a transcontinental railroad through the great mountain barrier of California. The party was delighted to find the fine, low natural gateway of San Gorgoñio Pass, which they considered the best pass in the Coast Range. In it was the ranch of a Mr. Weaver, who had settled there several years before. The narrative of this discovery is an interesting record. The expedition descended the Coachella Valley to the Salton Basin, which was ascertained to be several hundred feet below sea level. The scarcity of water, however, made this route too difficult for caravans, and the old route by way of San Felipe Creek and over the high divide as described above was preferred until after the railroad was built through in 1879;[85] then wells were sunk and water found in the deposits underlying the valleys. Now there is ample supply at short intervals, especially along the main highway, which passes up the valley to San Gorgonio Pass but goes by way of El Centro and along the southwest side of Salton Sea. Water at Palm Springs, Toro Spring, Agua Dulce, and Indian Wells has long been utilized by the resident Indians, as well as by their predecessors the Cajuenches, a tribe of Yuman stock who were found by Garcés occupying the Colorado Desert region as far west as San Gorgonio Pass.

With increase in elevation the vegetation of the valley floor as well as that of the mountain slopes changes rapidly, and the desert flora ceases near the 1,500-foot contour. This, however, is largely due to the fact that considerable moist air comes through San Gorgonio Pass at times, and on the mountains there is much more precipitation than in the desert ranges to the east. The Spanish bayonet (*Yucca mohavensis*) is conspicuous near Cabazon siding and for some distance west. (See pl. 42, *A*.)

From the vicinity of Cabazon (misspelling of Spanish cabezón, big head) westward there are very impressive views of the mountains, especially of the San Bernardino Mountains, to the north. As shown in Figure 64, there are wide, flat-topped foothills on the north side of the valley.

[85] In 1876 a stage line crossing the Colorado River at Ehrenberg, 60 miles above Yuma, came by way of Dos Palmas Spring, east of Mecca, and thence up the Coachella Valley to San Gorgonio Pass.

Banning.
Elevation 2,320 feet.
Population 2,752.
New Orleans 1,915 miles.

Banning, near the head of the valley constituting San Gorgonio Pass, is an agricultural and residential settlement where high elevation and other conditions make it an agreeable summer resort as well as an all-year residence. The mean annual temperature is about 60°, the average humidity ranges from 42 to 53 per cent, and the mean annual precipitation is 18.5 inches. It is claimed that there is an average of 345 days of sunshine in the year. The views of the mountains to the north and south are very impressive, and roads lead from Banning into both ranges. The great crest of San Gorgonio Mountain (elevation 11,485 feet), a few miles north of the pass, is most conspicuous, and often its summit remains snow-covered long after the fruit trees of the lowlands are in blossom. This is the highest point in southern California. San Jacinto Peak is also a prominent feature not far to the southeast.

The water used for irrigation at Banning is taken from the San Gorgonio River, which has an average flow of about 16 second-feet. There are many orchards of peaches, prunes, almonds, and other fruits near Banning, and through Pershing siding to Beaumont and beyond, almond trees blossoming in early February are an attractive sight. The 28-mile tunnel to carry water from the Colorado River at Parker to Los Angeles will pass near Beaumont, where it will be about 800 feet below the surface. This water is to be impounded by the Boulder Dam.

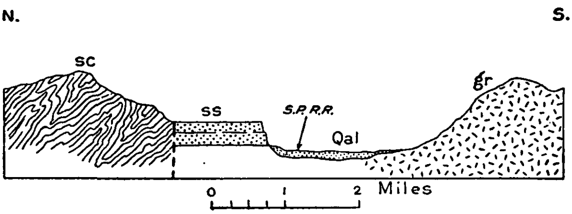


FIGURE 64.—Cross section of San Gorgonio Pass near Cabazon siding, Calif., looking east. gr, granite; ss, sandstone; sc, schist; Qal, alluvium

The San Bernardino Mountains (see fig. 65) consist of a great mass of schists of various kinds, greatly contorted and invaded by granites, some of which have also become schistose owing to movement and great compression. There are excellent exposures of these rocks in the canyons of Smith Creek and the San Gorgonio River northeast of Beaumont. On the south side of the San Bernardino Mountains the schist laminae dip 30° NE., and the peak called San Bernardino Mountain (10,630 feet above sea level) consists of biotite schist. The rocks around San Gorgonio Mountain range from biotite granite to schist, both intruded by granite. From the Whitewater River to Deep Canyon the schists dip mostly 20° N., with many local variations. The great offset in the mountain front at the Whitewater River referred to above is due to faulting. (Vaughan.)

Snow is conspicuous in winter on the higher ranges in southern California, but it disappears in summer. Formerly there were small local glaciers on the San Bernardino Mountains, as shown by well-preserved cirques and moraines.[86] The moraines do not extend far beyond the cirques, and there are no typical glaciated valleys. The detritus is angular, and the boulders are not striated. A typical cirque on the northeast side of San Gorgonio Mountain is about 1,500 feet long, 1,000 feet wide, and 1,200 feet deep. It contains a terminal moraine 250 feet high and two small recessional moraines that mark stages in the shrinking of the glacier. Doubtless the last glacial ice disappeared many centuries ago. Other features of former glaciation occur at the head of Hathaway Creek, just north of San Bernardino Mountain, where there was a tongue of ice about a mile long. None of these glaciers extended below an elevation of 8,500 feet, and they were all on the northward-facing slopes.[87]

North of Banning is the Morongo Indian Reservation. Padre Font, who was the chronicler of Anza's expedition in 1774, described some Indians living hereabouts whom they named Danzarines (Span-

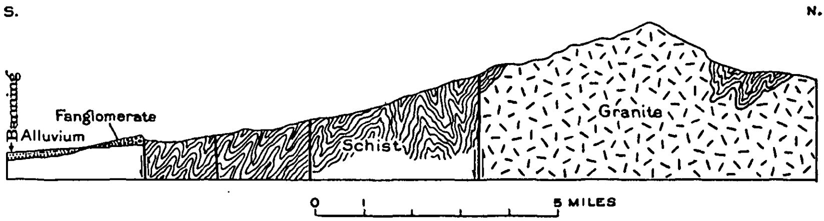


FIGURE 65.—Section from Banning, Calif., north to San Bernardino Mountain. After Vaughan

ish danzarín, a fine dancer), because of their habit of gesticulating constantly while talking.

A short distance east of Beaumont the railroad passes through the wide saddle between the San Jacinto and San Bernardino Ranges at an elevation very near 2,600 feet, leaving the drainage basin of the Gulf of California and entering a region where the streams flow directly into the Pacific Ocean, which at its nearest point lies 55 miles almost due southwest of Beaumont.

Beaumont is an agricultural settlement and year-round resort. From Beaumont west there is a down grade past Nicklin and Hinda sidings into the San Timoteo Canyon, which leads to the Santa Ana River. In the upper part of this canyon there are at intervals fine views of the mountains to the north, but finally high banks cut off the view. San Timoteo Canyon is excavated in a deposit of loam, sand, gravel, and cobblestones of Pleistocene age. These ma-

Beaumont.
Elevation 2,564 feet.
Population 1,332.
New Orleans 1,921 miles.

[86] Cirques are steep-walled semicircular recesses in the high mountain slopes, produced by glacial erosion, and moraines are ridges of coarse ice-borne detritus that accumulates along the margin of glaciers as the ice melts.

[87] Fairbanks, H. W., and Carey, E. P., Science, new ser., vol. 31, pp. 32–33, 1910. Vaughan, F. E., California Univ. Dept. Geology Bull., vol. 13, p. 335, 1922.

terials are well exposed in gullies and banks in the adjoining hill slopes. Together with underlying deposits of Pliocene age they constitute the wide ridge of badlands on the south separating San Timoteo Canyon and San Jacinto Valley. The materials here are mostly coarse sand and cobble beds in a matrix of sand, underlain by soft sandstones and shales of gray-brown, yellow, and reddish tints. The structure of the ridge is strongly anticlinal, the beds on the north side and center dipping northeast and those on the south side dipping southwest into the Moreno-San Jacinto Valley. The axis of the anticline is some distance south of the crest of the ridge. It is covered by valley fill in slopes 20 miles west of Beaumont, but its extension to the northwest is shown in Bunker Hill and other outcrops to the northeast. Some features of the steeply dipping beds are shown in Plate 43. There are fine exposures of them on the highway that crosses the ridge 3 miles west of Beaumont. The strata forming this ridge, especially the lower members, contain many bones of extinct animals, comprising camels, a large and a medium-sized horse, ground sloth, tortoise, peccary, antelope, saber-tooth tiger, mastodon, rabbit, bear, and others—an assemblage of late Pliocene and early Pleistocene time, creatures mostly very different from the present fauna. (Frick.)

It is believed that in late Pliocene time southern California had somewhat the same configuration as at present. The land was gradually rising, and on the narrow coastal margin was deposited a thick succession of marine beds. Much of the material was sand and clay of local origin. The animals were an assemblage of forms that would now look strange in this region. In the open meadows were droves of slender-limbed horses, various kinds of camels, including two of giant size, and many antelope and deer. In the brush were pigs, the large boar, and tapirs, and in the forest were saber-toothed tigers, ground sloths, wolves, and bears larger than the great Kodiak bear of Alaska. From the time of deposition of the lower sediments to that of the upper ones, there was considerable change in the fauna and the horses especially became larger and of a more advanced type. It is estimated that this was considerably more than a million years ago. (Frick.)

The Tertiary and overlying formations lying on the granite south of Beaumont and extending westward nearly to Riverside have a total thickness of more than 4,000 feet. At the base is about 1,800 feet of red conglomerate and sandstone, unconformably overlain by about 1,500 feet of sandstone and shale, all of late Tertiary age. The lower beds are well exposed along Potrero Creek and its tributaries, south of Beaumont. (Frick.)

The uplift and flexing of the strata in the ridge south of San Timoteo Canyon were geologically recent, probably contemporaneous with the early part of the uplift of the San Bernardino Mountains. It is probable that at the same time the San Bernardino Valley subsided somewhat, so that its rock floor, sheeted over by silt and sand, stood at a lower level than at present. Streams cut deep canyons in the mountains and carried boulders, rocks, and clay out over the plain until many hundreds of feet of alluvial material was accumulated. (Mendenhall.)

On approaching El Casco siding there is in view a steep-sided gully cut in the relatively level valley floor of fill, showing that there have been two stages of valley development—an earlier one, followed by some deposition, and the present one of invasion by a stream cutting rapidly to a lower grade.

A few miles farther down grade San Timoteo Canyon opens into the eastern part of the San Bernardino Valley, which is traversed by the Santa Ana River, a large stream draining an area of considerable extent in the San Bernardino Mountains and used extensively for irrigation. Probably no other stream of its size in the United States is made to serve more varied uses. In its course of not more than 100 miles from the headwaters to the ocean the same water is used at least seven times for power and irrigation, by means of artificial storage, diversion into canals, and recovery of seepage water by pumping.[88]

Redlands.
Elevation 1,350 feet.
Population 14,177.
New Orleans 1,940 miles.

The railroad passes through Redlands station 3 miles south of the fine city of Redlands, which is noted for its oranges (see pl. 42, *B*) and for the beauty of its environment. A park including Smiley Heights, with a notable collection of fine trees, offers some spectacular drives with charming views of great orchards and vistas of the stately San Bernardino Mountains, their higher peaks capped by snow for a large part of the year. (See pl. 44, *A*.) Six miles northeast of Redlands is the deep canyon of the Santa Ana River, which is followed by a road that gives access to some of the many resorts in the higher parts of the San Bernardino Mountains. Near by are the Urbita Hot Springs, with a large swimming pool and sulphur and mud baths. The Redlands district is at the eastern margin of the great orange belt of southern California. The soil is favorable, being a porous sandy loam that keeps free from alkali under irrigation, and much of the land is sufficiently high to be safe from frost, which occasionally occurs in the lower part of the valleys on chilly mornings. Water for irrigation is both pumped from the large underflow from the Santa Ana Wash and diverted from the Santa Ana River and Mill Creek.

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[88] See U. S. Geol. Survey Water-Supply Paper 636, pp. 176–177, 1930.

The Santa Ana River is crossed about 7 miles west of Redlands and the city of Colton is entered. Colton is an important commercial and railroad center. Among many other industries it has a large plant for icing refrigerator freight cars that carry fruits and other perishable products on the long trip across the warm Imperial Valley and the deserts of southern Arizona and New Mexico. In this region the mean annual precipitation is about 14 inches, varying usually from 10 to 18 inches. The humidity is generally only 30 to 40 per cent, so that the summer heat is seldom uncomfortable.

Colton.

Elevation 978 feet.
Population 8,014.
New Orleans 1,944 miles.

Colton has a cement works with a capacity of 3,000 barrels a day, using the marble that constitutes Slover Mountain, just west of the city, and there is another large plant near Riverside. Southwest of the city many small peaks of granite rise above the plain.

Riverside (population 29,696, an increase of more than 50 per cent from 1920 to 1930), visible 7 miles south of Colton, is one of the greatest orange-shipping centers in the world, receiving nearly $4,000,000 yearly for its output. (See pl. 45.) The city is famous for its general beauty, the original navel orange tree, the Mission Hotel, and Magnolia Avenue, with its 10 miles of quadruple rows of eucalyptus, pepper, palms, and magnolias. A portion of this avenue is shown in Plate 44, *B*. The parent of millions of orange trees (which in 1874 came to Riverside as a seedling sent by the Department of Agriculture) now stands protected by a high railing, in a position of honor in front of Mission Inn, where President Theodore Roosevelt replanted it in 1903. The county courthouse and the high school at Riverside are notable examples of architectural achievement. There is also a large Indian school. On Mount Rubidoux is a cross dedicated to the memory of Padre Junípero Serra. This knoll takes its name from a trapper who owned the Jurupa ranch, the site of Riverside, which at first was named Jurupa.

The name San Bernardino Valley was given by Garcés in 1774 to the plains adjacent to the upper portion of the Santa Ana River, but it is now applied to the continuation of these plains that extend for 90 miles along the south side of the east end of the San Gabriel Mountains to and beyond Pomona, an area of about 1,500 square miles. This valley is filled with débris of unknown thickness, and its surface is made up of deposits of sand, silt, and gravel, the talus and wash from the adjacent ranges. The elevation along its north side is about 2,000 feet, and the distance from its southern margin to the ocean is about 50 miles. To the south and west are low ranges, the chief of which is the Santa Ana Mountains, culminating in Santiago Peak, 5,680 feet high, visible on the southwestern horizon.

To the northeast are many high peaks of the San Bernardino Mountains, which were skirted by the railroad from Whitewater to Beaumont. These peaks are often visible from ships at sea.

On the south slope of these mountains, near Arrowhead Springs, there is a remarkable scar, like a huge arrow point. (See pl. 46, *A*.) It is not always conspicuous, its distinctness depending on light and foliage, but it can be easily discerned on close scrutiny. It is due to a peculiar-shaped area of bare rock ledges and thin vegetation, 1,375 feet long and 449 feet wide, occupying an area of 7½ acres. Near by is an interesting group of hot springs, some of which have temperatures exceeding 180° F.; here buildings have been erected to form a health resort. The water rises on the fault that defines the south margin of the range, and the heat is due to the great depth from which it comes.

Three miles north of Colton is the prosperous city of San Bernardino (population 37,481), the county seat of San Bernardino County. This is the largest county in the United States, having an area of slightly more than 20,000 square miles, or almost equal to that of Massachusetts, Connecticut, and New Jersey combined. San Bernardino is built on the plain, about 5 miles south of the foot of the San Bernardino Mountains, and in the last 30 years or so it has grown into a large modern city with many industrial interests. About 15,000 acres of land in the surrounding region is under cultivation, mostly irrigated by water from wells, many of them flowing, which draw their supply from the gravel and sand that constitute the plain. San Bernardino was the first Anglo-Saxon settlement in southern California, established in 1851 by a colony of Mormons sent from Utah by Brigham Young. They came through Cajon Pass (cah-hone′) and purchased from Mexicans the cultivated areas of the Bernardino ranch for $7,500. The region had long been occupied by settlers of Spanish origin. In 1810 a mission was established near Bunker Hill, but it was destroyed by the Indians. Later a larger one was begun at old San Bernardino, on the south side of the Santa Ana River. There the padres in charge dug ditches, beginning between 1820 and 1830 with one from Mill Creek, which is the oldest ditch in the valley. In 1837 the mission lands were taken by the Mexican Government and given to Mexican settlers, and it was from one of these landholders that the Mormons purchased land for their settlement.

At first the old ditches sufficed for the needs of the settlers, but as population increased other ditches were dug. In 1870 the Riverside colony, made up mainly of settlers from New England, began the first large canal, and in the next 20 years irrigation was extended over a wide area. The greater part of the running water and considerable underground water was utilized, mainly for irrigating oranges and other citrus fruits. Now a large area in the vicinity of San Bernardino, Redlands, and Riverside is under irrigation by water derived either from surface streams from the San Bernardino Mountains or from the underflow in the gravel at their foot.

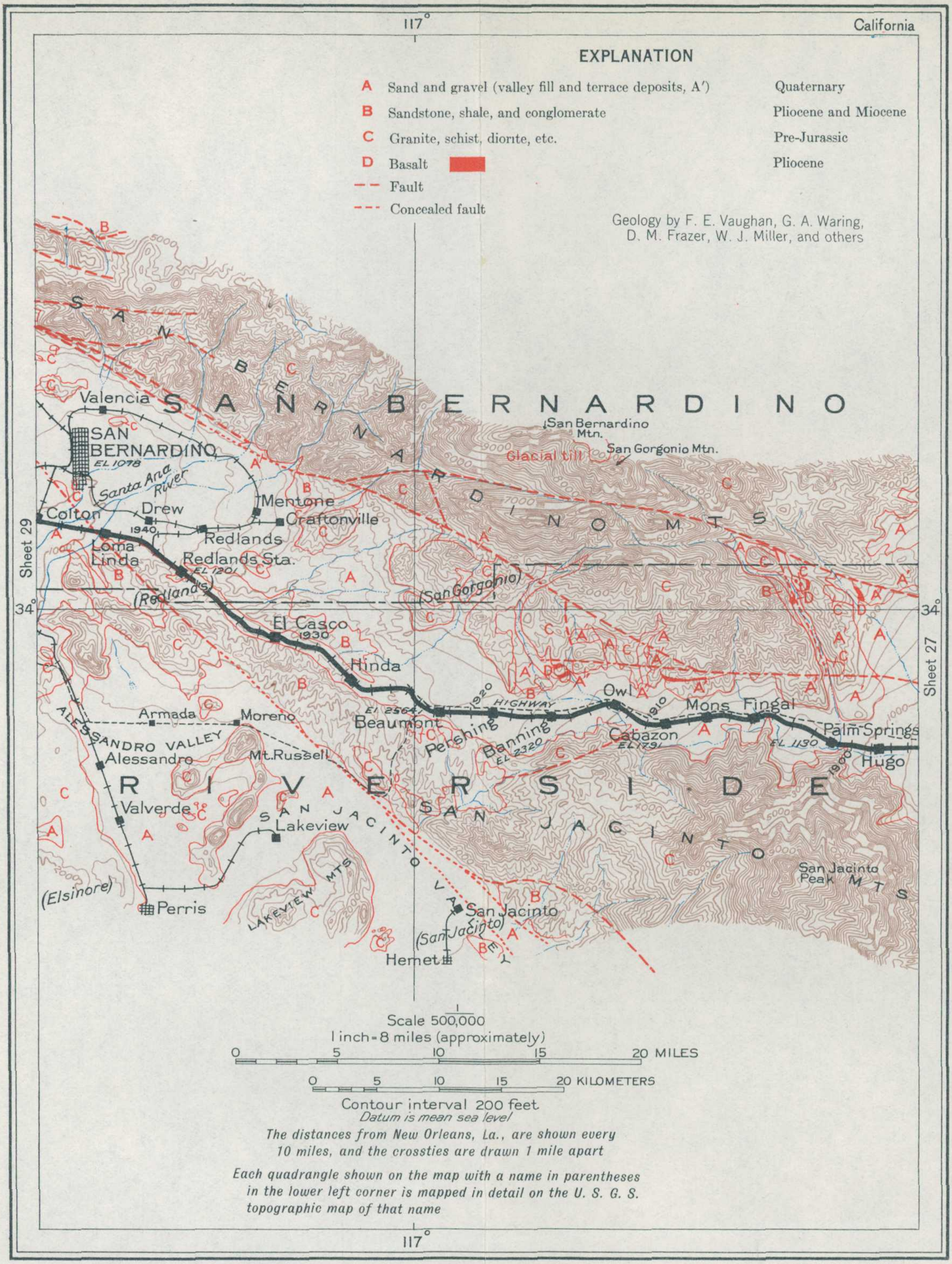
It was soon found that the best conditions for citrus growth were on the benches, where there was less liability to the low temperatures that sometimes kill the trees in the valley bottoms. The first orange trees were seedlings grown in old San Bernardino, but it was not until the Riverside colony of 1870 was established that marketing of oranges began. The Bahia navel orange was first introduced at Riverside. The original cuttings, from Bahia, Brazil, were sent to Florida from Washington, but someone, whose identity is unknown, took two of these cuttings to California. One of these two and all the cuttings in Florida died, so that the present enormous business in navel oranges has grown from the slender beginning of a single cutting. The tree that lived may still be seen at Riverside.

The principal factor in the orange business was an outlet to eastern markets; and after the building of the railroads production increased rapidly and finally attained the present great proportions. As the demand for water increased the methods of irrigation were improved, first by avoiding waste and then by careful application, so that in ordinary practice the volume used was diminished from 1 miner's inch for 3 acres to about half as much.[89] In part of the region about San Bernardino artesian water is available. It flows under moderate pressure from the wells, but the heavy drain on this resource has reduced the volume and head of the water, so that the area in which flows are obtainable has greatly diminished. It was decreased temporarily by the dry period before 1900.

Much of the water is used in orange groves, but large tracts of other fruits, vegetables, and alfalfa are irrigated. Grapes, beans, and barley, which require less water and need irrigation only in dry seasons, are regarded as "dry" crops. Sugar beets are a very abundant crop, the refinery near San Bernardino using 40,000 tons a year. Oranges are available for a long period, the navels in winter and the Valencias in spring and summer. Lemons ripen practically throughout the year. In San Bernardino County vineyards cover 40,000 acres and give employment to many persons. (Turn to sheet 29.)

Northwest of Colton is Cajon Pass (see fig. 66), a great break between the San Gabriel Mountains on the west and the San Bernardino Mountains on the east, which is utilized by the Atchison, Topeka & Santa Fe Railway and by the highway that crosses the Mohave Desert. Through it also passed the Mormon trail, much used by the gold seekers of 1849. The pass is due to erosion along several parallel faults,

[89] A miner's inch (in California) is the amount of water that flows continuously through an orifice 1 inch square under a head of 6 inches. It equals 11¼ gallons a minute, 1/40 second-foot, or 1 foot deep over 18.1 acres in a year. (The older miner's inch was 1/50 second-foot.) Citrus lands require about 1 miner's inch for every 5 acres.



Topography: U. S. Geological Survey quadrangle maps

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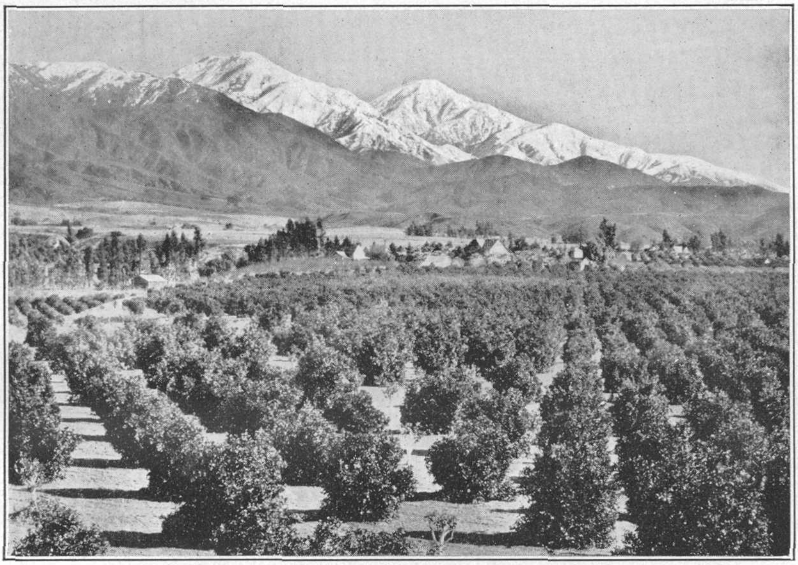
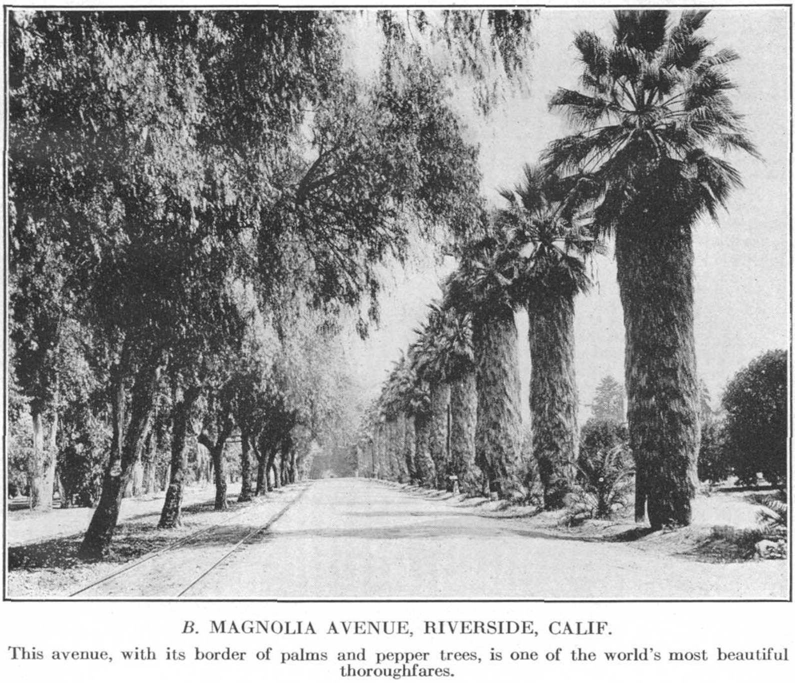
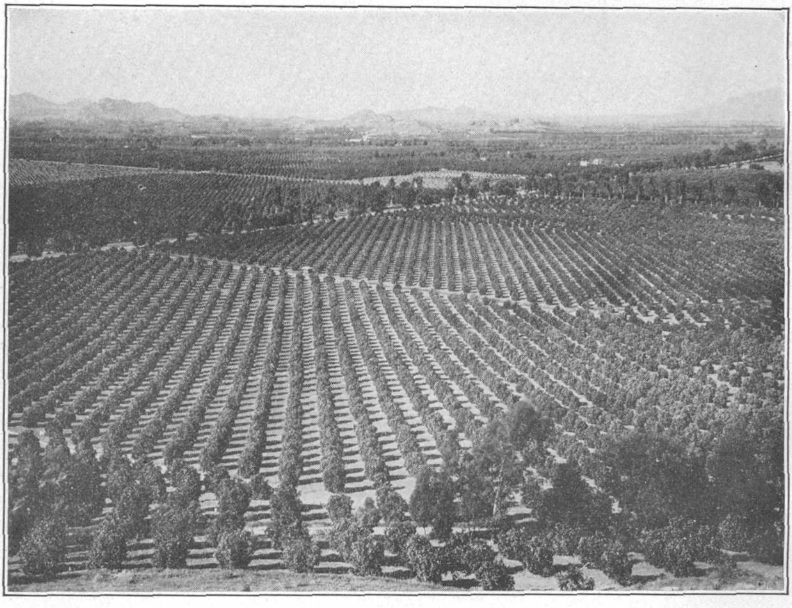


A. SAN BERNARDINO PEAK FROM POINT NEAR REDLANDS, CALIF.
The snow-capped mountain overlooks orange trees in fruit.

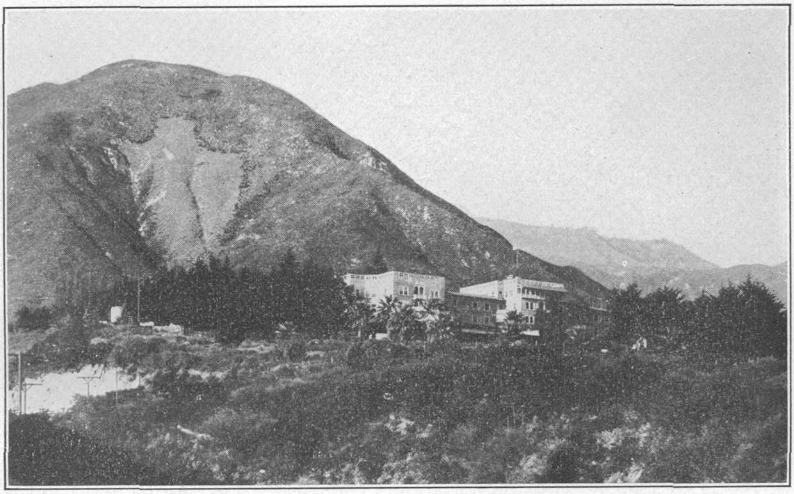


B. MAGNOLIA AVENUE, RIVERSIDE, CALIF.
This avenue, with its border of palms and pepper trees, is one of the world's most beautiful thoroughfares.

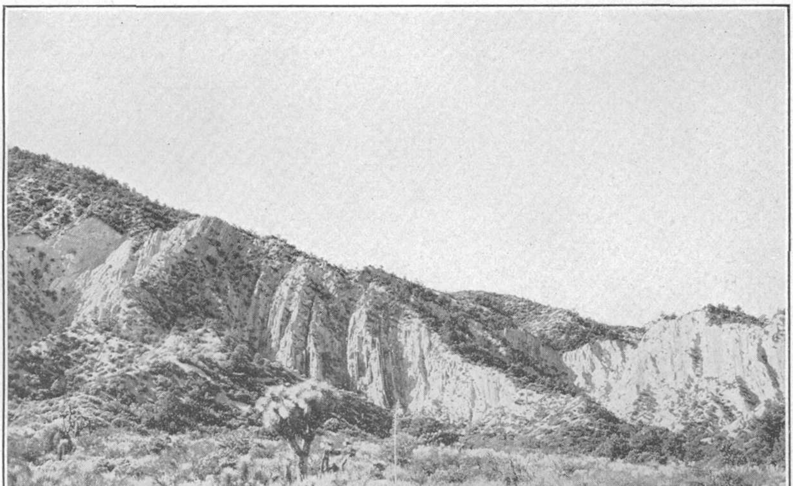
A. PICKING LEMONS NEAR RIVERSIDE, CALIF.



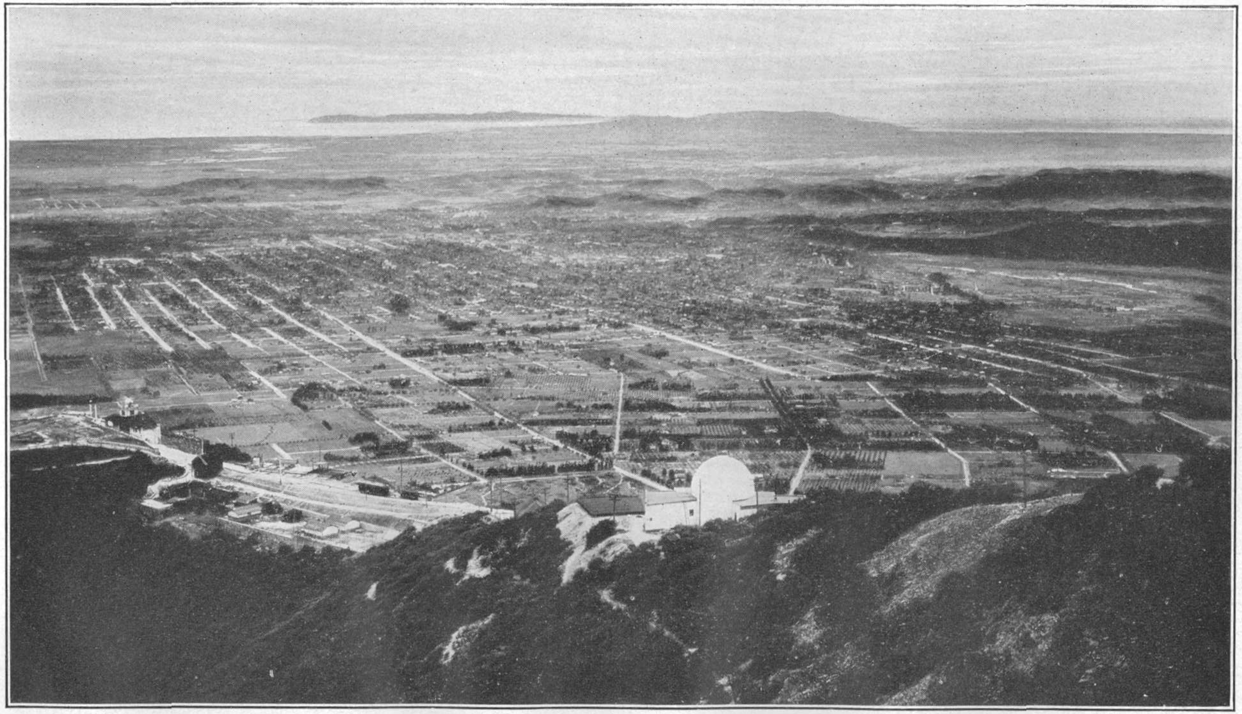
B. ORANGE GROVES NEAR RIVERSIDE



A. THE GREAT ARROW-SHAPED SCAR IN THE MOUNTAIN SIDE AT ARROWHEAD SPRINGS, ON SOUTH SLOPE OF SAN BERNARDINO MOUNTAINS, CALIF.



B. UPTURNED LATE TERTIARY STRATA IN CAJON PASS, NORTHWEST OF SAN BERNARDINO, CALIF.



LOS ANGELES PLAIN, CALIF., FROM ECHO MOUNTAIN

Looking southwest. Pasadena in middle ground; Los Angeles at right; San Pedro Point in distance.

of relatively recent age geologically, that cross diagonally the axis of the general mountain range extending across southern California. These faults include the southern extension of the San Andreas fault, movement along which in 1906 caused the San Francisco earthquake They define the north side of the San Gabriel Mountains, and southeast of the pass they extend eastward for many miles along the south foot of the San Bernardino Mountains. There are several planes of movement, not far apart, with huge slivers, or narrow blocks, of schist and soft sandstone between them. (See pl. 46, *B*.) The erosion of the sandstone on the downthrown blocks is the principal cause of the pass. (Noble.)

Near Redlands the faults present many features indicating recent movement, notably at one place where a ravine has been offset abruptly. The movement was mostly vertical, but in some of the faults there has been a horizontal displacement.

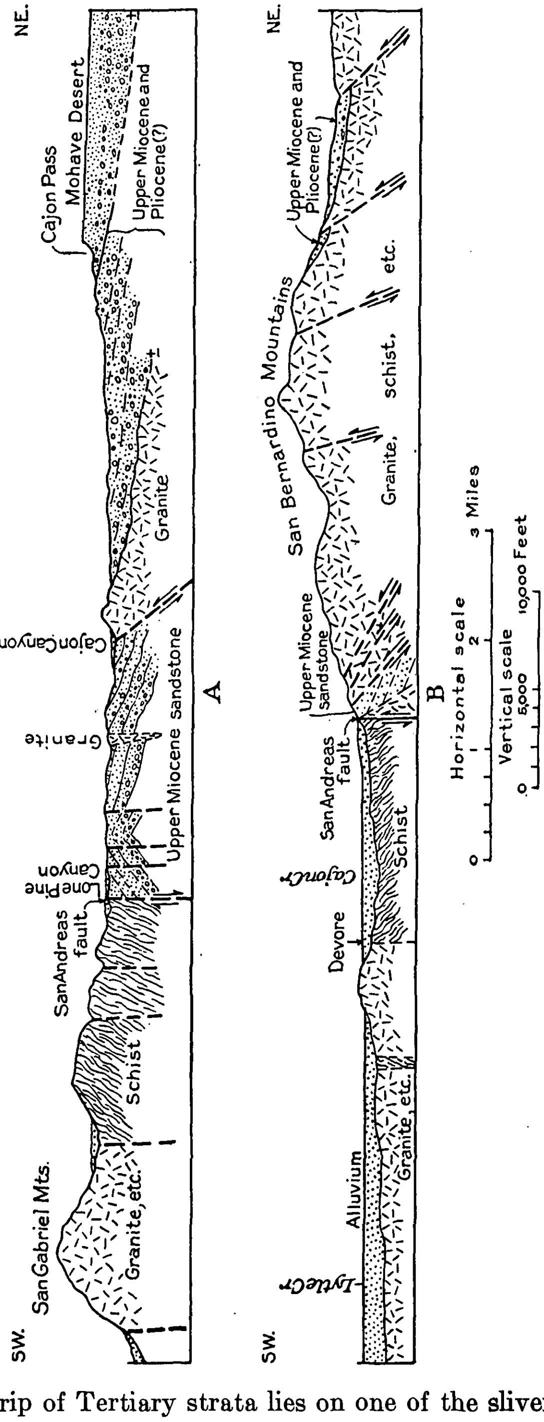


FIGURE 66.—Sections northwest of San Bernardino, Calif. A, Through Cajon Pass; B, near Devore siding. After Noble. For location see sheet 29

For some distance a strip of Tertiary strata lies on one of the slivers between the faults, bordered on each side by the old schists. In general in this vicinity the faults are bordered on the north by sandstone of Tertiary age lying on gneiss or schist, and on the south side is schist more or less heavily covered by young gravel. (Noble.)

Although the San Gabriel and San Bernardino Mountains contain similar rocks, are separated only by Cajon Pass, present identical relations to the valley of southern California and to the Mohave Desert, and are both uplifted fault blocks, they are very dissimilar in configuration. The San Gabriel Mountains are deeply cut by canyons containing graded streams and are made up of separate sharp peaks and knifelike ridges of various heights; no level areas remain, either about the summits or in the valley bottoms. The higher part of the San Bernardino Mountains has a very different character, for its west end, at least, presents a strikingly level sky line, mostly at elevations from 5,000 to 6,000 feet, and the range contains many broad valleys, some with meadows and lakes, separated by rolling ridges, a topography of an old and well-reduced type. According to recent observations by Noble this condition is due largely to the relatively recent removal of Tertiary deposits from the plain on which they were laid down. Remnants of these strata remain in places. To the east, where the elevation increases, San Bernardino Mountain and San Gorgonio Mountain rise considerably above the general level. Along the lower margins of the range the forms are strikingly new, and several of the streams are not reduced to grade but after meandering through the broad uplands plunge over falls into steep canyons in the front of the range. These differences in the configuration of the two ranges are not related to rock texture, drainage pattern, or difference in precipitation; it is suggested that the San Bernardino fault block was uplifted much later than the block constituting the San Gabriel Range, which has preserved none of these old forms. (Mendenhall.)

Bloomington.

Elevation 1,090 feet.
New Orleans 1,948 miles.

Bloomington, a small place 4 miles west of Colton, is in the midst of a thriving irrigation district with many groves of oranges and olives. To the north is a fine view of the San Gabriel Mountains,[90] with their imposing high peaks and deeply incised canyons. Along the foot of the range is the main fault, but it is everywhere buried under valley fill. Just south of Bloomington are the Jurupa Mountains, rising about 1,000 feet above the plain; they consist of quartzite,

[90] The San Gabriel Mountains consist of granite rocks of several kinds and a variety of other crystalline rocks, mainly schists, some of which were originally shales and sandstones but have been altered (metamorphosed)

schists, and crystalline limestones, all metamorphosed sedimentary deposits, penetrated by granitic and other igneous rocks. Their length is about 5 miles, and they are surrounded by valley lands. Beyond the west end of this range is the north end of the high Santa Ana Mountains,[91] which extend southeast from Corona.

From Bloomington to Ontario there are several settlements occupied with the extensive culture of grapes, lemons, peaches, and other fruits. In this region the San Bernardino Plain is more than 20 miles wide, extending from the foot of the San Gabriel Mountains to the Santa Ana River which flows near its southern margin. It is bordered on the west by the San Jose and Puente Hills, which make a barrier trending north-northwest, beyond Pomona. To the north near Guasti are fine views of Cucamonga Peak (elevation 8,911 feet), one of the high summits of the southern ridge of the San Gabriel Mountains, and the still higher San Antonio Peak (elevation 10,080 feet) is farther back on the northern sky line. Deep canyons lead out of these mountains at short intervals, and most of them contain streams whose water, if not diverted by irrigation ditches, sinks at the mouths of the canyons and passes as a general underflow into the gravel and sand of the slope beyond. In times of freshet the streams flow greater or less distances across the slope, carrying much sediment, which is dropped as the water spreads out on the plain. Occasional great floods cross the plain, but much of the large volume of water they carry at such times is absorbed by the porous gravel of the stream beds. The courses of these ephemeral streams across the plain are marked by dry washes, usually shallow sandy channels, many of them splitting up irregularly and some of the branches rejoining. One effective method of conserving water in this region, where it is so valuable, is to divert flood waters near the canyon mouth, causing them to spread out widely over the coarse deposits, where they sink, thus adding to the volume of underflow tapped by many wells.

Guasti.
Elevation 958 feet.
Population 164.
New Orleans 1,959 miles.

by great igneous intrusions and compression. It is believed that the range was uplifted in greater part in late Tertiary time. Apparently the uplift consisted of the rise of a huge block of the earth's crust along fault lines mostly trending N. 60° W. The main block is traversed by minor faults which make the structure very complex.

91 In the Santa Ana Mountains the oldest rocks are Triassic slates and sandstones with some limestone lenses, intruded by dikes of andesite. They are overlain unconformably by a coarse conglomerate and in places by basic lavas and tuffs, and all are cut and altered greatly by masses of andesite, granodiorite, and diorite which have been intruded in a molten condition. Next above there is a westward-dipping succession of Upper Cretaceous and Tertiary strata. In general, the mountains consist of a tilted fault block with local flexures. There has been a long series of repeated uplifts, but in the development of the present topography the hardness of the rocks has been the principal factor. Some of the lower terraces are marine. (B. N. Moore.)

Six miles northwest of Ontario is the mouth of San Antonio Canyon, one of the larger drainage outlets from the San Gabriel Mountains, which furnishes considerable water for irrigation. On the plain the creek bed spreads into half a dozen irregular "washes," which are crossed by the railroad near Ontario. From the gravel and sand under the plain a large amount of water is pumped for irrigation. The water is conveyed in canals lined with concrete and is distributed in underground pipes so as to prevent loss by leakage and evaporation.

Ontario.

Elevation 991 feet.
Population 13,583.
New Orleans 1,963 miles.

Ontario, with its companion settlements, North Ontario, San Antonio Heights, and Upland, extends widely across the valley slope and up the foothills of the mountains. The settlement is traversed by a handsome tree-shaded boulevard, Euclid Avenue, which runs north to the foot of the mountains. Ontario is surrounded by many orange and lemon groves and other products of irrigation, and one of its chief industries is a fruit-canning establishment, claimed to be the largest in the State.

Pomona is a commercial, residential, and educational center, built on the western margin of the plain that extends from San Bernardino to the San Jose and Puente Hills. It is surrounded by extensive groves of oranges and other fruits and produces large amounts of walnuts and grapes. About Pomona were grown the first oranges shipped from California. The underground water supply is utilized for irrigation by pumping from hundreds of wells. Much attention has been given to making the landscape lovely with trees and gardening. At Claremont, not far north, are the Claremont Colleges, one of the most beautiful and outstanding institutions of learning in the coast region, and the Greek Theater, which seats 4,000.

Pomona.

Elevation 855 feet.
Population 20,804.
New Orleans 1,967 miles.

Three miles west of Pomona the railroad passes over a low divide between the San Jose and Puente Hills and descends the canyon of San Jose Creek. The San Jose Hills, to the north, consist mainly of a thick succession of shales and sandstones of the Puente formation (middle and upper Miocene). At their northeast end, 2 miles northwest of Pomona, there is granite [92] overlain by lava flows and volcanic tuffs and agglomerates at the base of the Tertiary section, and a similar succession on the south side of the railroad constitutes the

[92] The granite is well exposed in Ganesha Park, in the northwestern part of Pomona. It is much weathered, but its coarse crystalline texture is apparent. West of Pomona on both sides of San Jose Creek the granite is overlain by igneous rocks of Tertiary age containing flows of white, purple, and brown lavas and intrusive sills of dark basic rocks. Agglomerate, vesicular flows, and tuffaceous sandstone are also found in the area north of San Jose Creek constituting the east end of the San Jose Hills. South of Spadra a few blocks of sandstone are included in the intrusive rocks, and there is a vein of coarse calcite traceable for a mile or more, which was burned for plaster by the early Spanish settlers. (See p. 293.)

northeast corner of the Puente Hills. A section of the San Jose Hills north of Walnut is given in Figure 67.

The Puente Hills consist of sandstones and shales of the Puente formation,[93] 2,600 to 3,400 feet thick (middle and upper Miocene), with smaller exposures of underlying and interbedded shales, having the relations shown in Figure 68. The granites and slates of pre-Cretaceous age at the east end are separated from the sandstone member of the Puente by tuffs and tuffaceous sandstones, somewhat as shown in the lowest section in Figure 68. The Puente formation of this region (regarded as equivalent to the Modelo formation of the region to the west) is made up of an alternating succession of coarse and fine materials with many thick members of shale and sandstone. The upper shale includes beds carrying the remains of minute marine plants and animals, principally diatoms and Foraminifera; the more richly diatomaceous portion is nearly white and of chalky texture.

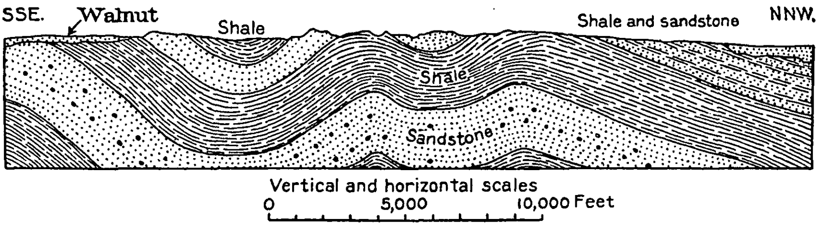


FIGURE 67.—Section of San Jose Hills about 7 miles west of Pomona, Calif. After English and Kew. All Puente formation

At the west end of the hills, south and west of Puente, overlying shales and sandstones of the Fernando group (Pliocene) are extensively exposed, and they are dropped by a fault extending along the south side of the Puente Hills, passing just north of Whittier and along La Habra, La Brea, and Olinda Canyons. The Fernando group carries a fauna of marine shells of Pliocene age and is nearly 5,000 feet thick. (English and Kew.)

On the upper slopes of the western part of the Puente Hills, about 5 miles southwest of Walnut, was the old Puente oil field, one of the

[93] According to the definition of the Puente formation by the U. S. Geological Survey, in the Puente Hills and Los Angles district it comprises the following members:

- Upper shale, 300 to 2,000 feet. Earthy chalky shale and sandy gray shale, weathering pink to chocolate-brown, with a few beds of fine yellow sandstone. Is overlain unconformably by Fernando group.
- Sandstone member, 300 to 2,000 feet. Moderately coarse gray to tawny-yellow thick-bedded sandstone with beds of shale; some conglomeratic members containing granite boulders.
- Lower shale, 2,000 feet. Chiefly earthy shale, mostly gray to black, including thin beds of fine-grained sandstone from top to base and lentils of limestone.

earliest fields discovered in California. The first well was completed in 1880, and at the end of 1912 there were 470 producing wells with an annual output of 7,000,000 barrels and an aggregate production of 41,000,000 barrels. The wells were in the outcrop area of the thick body of shales constituting the lower half of the Puente formation,

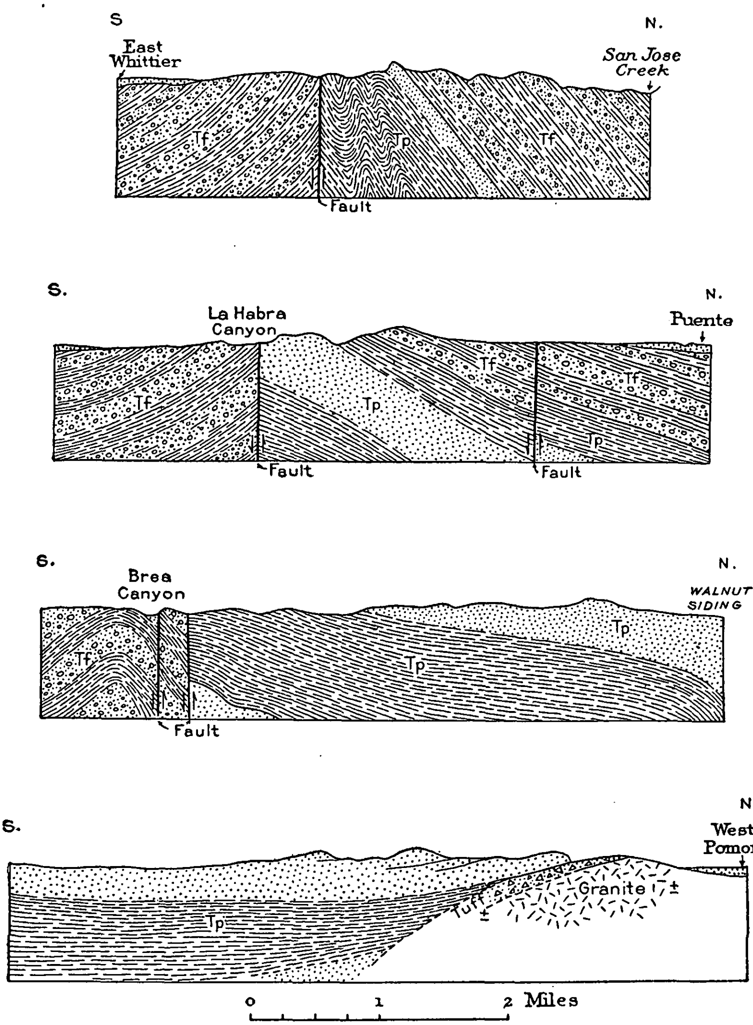


FIGURE 68.—Sections across Puente Hills, Pomona to Whittier, Calif. After English and Kew. Tf, Fernando group (Pliocene and Pleistocene), Tp, Puente formation (Miocene)

and the oil is thought to have migrated from the great oil fields to the southeast. The depths of the wells were mostly from 1,000 to 2,000 feet. The large oil production of this general region now comes from the Santa Fe, Whittier, Brea Canyon, Coyote Hills, and other fields along the south slope of the Puente Hills or south of them.

Puente is the center of a great walnut district which produces more than 13,000,000 pounds of walnuts a year (1929). Near Puente the railroad leaves the valley of San Jose Creek and the Puente Hills and passes into the wide basinlike plain bordering San Gabriel Wash, into which flows the San Gabriel River, a stream that rises in deep canyons far back in the San Gabriel Mountains. This wash is crossed a mile west of Bassett, but there is usually little water in it here except during rainy seasons. The river water is used for irrigation, but much of it is underground, where it is available for pumping. Some of this underflow comes out again in Lexington Wash, near El Monte. In times of freshet a large volume of water passes down San Gabriel Wash, as may be inferred from the large boulders in its bed. These boulders are crushed for road material.

Puente.
Elevation 320 feet.
Population 1,034.
New Orleans 1,982 miles.

From Bassett to San Gabriel the railroad goes northwest across a broad plain, most of which is in a high state of cultivation, with numerous fruit and walnut orchards, beautiful gardens, and verdant fields, all irrigated by water pumped from the underflow.

As the train progresses northwestward the San Gabriel Mountains are approached and there are fine views, notably of San Gabriel Peak (elevation 6,152 feet). This great mountain range consists of a huge block of the earth's crust uplifted along profound breaks, one of which, the Sierra Madre fault, follows the south foot of the range, and another, the San Andreas fault, extends along its northern margin. These are very recent faults, for the main upheaval was at the end of Tertiary (Pliocene) time. Doubtless there was a prior mountain range in front of the site of the present San Gabriel Mountains, which furnished sediments to the pre-Pliocene formations, but the form and relations of mountains and plains at that time can hardly be conjectured. An uplift of this kind may have progressed very slowly. There was not only the general axial uplift of the range but cross faulting, which has broken the main block into huge fragments with varying degrees of tilt and amount of uplift. The planes of the main faults dip steeply to the south, at least in the west end of the range, so that the granite and gneiss of the range are relatively thrust over the strata of Tertiary age, which are considerably flexed and in places also faulted. (M. L. Hill.) In the portion of the range north of Los Angeles the rocks are schist, quartzite, and marble, old sediments greatly metamorphosed and penetrated by a large amount of igneous rocks. Granite invades the metamorphic rocks very extensively, and there are also large masses of diorite and granodiorite and some hornblendite. (W. J. Miller.)

San Gabriel.

Elevation 415 feet.
Population 7,224.
New Orleans 1,992 miles.

The old San Gabriel Mission is a few rods south of the tracks at San Gabriel station. It was the fourth of the many missions established by the Franciscan friars between San Diego and San Francisco and is in an excellent state of preservation. It was started by Padres Cambón and Somera, under the direction of Fray Junípero Serra, September 8, 1771, and the building is typical of the architecture introduced by the friars. Early in its history a ditch was built to bring water for irrigation and for horses, cows, pigs, sheep, and chickens. The region was then inhabited by Indians, who were stolid, mild mannered, and rather ugly in features. They were not forcibly Christianized but were treated so well that many desired to live at the missions and be instructed. As the community prospered and settlers came in, the poor little hovels of adobe and reeds were replaced by finer buildings. The present village is in the midst of groves of oranges, avocados,[94] and walnuts, with many fine gardens. In 1850 Roy Bean, later famous as "the dispenser of the law west of the Pecos" at Langtry, Tex. (see p. 83), ran a dance hall and gambling saloon at San Gabriel, at that time a typical frontier town. The history of the beginnings of California is pictured yearly in the Mission Play by the poet John Steven McGroarty, done in the beautiful playhouse adjoining the San Gabriel mission.

Alhambra.

Elevation 456 feet.
Population 29,472.
New Orleans 1,995 miles.

Alhambra is an extensive settlement largely devoted to the growing of fruits, vegetables, and walnuts. There is a branch railroad from Alhambra to Pasadena, a city of 76,086 inhabitants a few miles to the north. This large and beautiful city is a most interesting business, residential, and educational center. In the eastern part is the California Institute of Technology, founded in 1891, which now includes among other buildings or departments the Bridge Laboratory of Physics, the High Potential Research Laboratory, the Gates Chemical Laboratory, the Guggenheim Aeronautical Laboratory, the Seismological Research Laboratory, the Dabney Hall of Humanities, and the Kerckhoff Biological Laboratories. Near by is the great Huntington Library and Art Gallery. The observatory on Mount Wilson, one of the units of the Carnegie Institution of Washington, is equipped with the world's largest reflecting telescope.

Pasadena lies in a "rincón," or corner, between hills and mountains, so that it has protection from winds and a slightly greater rainfall than some of the regions farther east and south. The name is an

[94] The fruit called aguacate by the Mexicans and other Spanish-speaking people now has the commercial name "avocado" to replace the former "alligator pear," which was a decided misnomer, as the fruit is not a pear and is in no way associated with alligators.

Indian word meaning crown of the valley. To the north are the high San Gabriel Mountains, with two conspicuous summits, Mount Lowe (elevation 5,650 feet) and Mount Wilson (5,750 feet), from both of which there are extensive views of the Los Angeles Plain. (See pl. 47).

The Repetto Hills west and south of Alhambra consist of sandstone, conglomerate, soft siltstone, and shale of Miocene, Pliocene, and possibly Pleistocene age, flexed in basins and arches. Part of the shale of upper Miocene age is diatomaceous. These rocks are of marine origin and indicate that during the later part of Tertiary time the region was submerged by the sea at intervals, and sand and mud were deposited in wide estuaries and along beaches. There was a long epoch of general subsidence, so that a great thickness of these materials accumulated. They have since been consolidated, uplifted, flexed, and faulted, and later terraces and plains have been developed on their surface. (Reed.)

After passing out of this narrow belt of hilly country the railroad enters the coastal plain that extends south and west to the Pacific Ocean. This plain consists of lowlands abruptly margined to the north by the Santa Monica Mountains, Repetto Hills, Puente Hills, and Santa Ana Mountains. Much of the region is a plain sloping gently seaward, but its continuity is interrupted by hills and ridges of considerable prominence, such as the Baldwin Hills, Dominguez Hill, and Signal Hill. In general it is floored with alluvium derived from the adjoining highlands and the mountains to the north. In a few places, however, the rocks have not yet been covered by alluvium. The plain is widest in the Los Angeles region, where it extends 25 miles south from the Santa Monica Mountains and with an area of nearly 2,000 square miles constitutes the combined delta of the Los Angeles, San Gabriel, and Santa Ana Rivers. At its inner edge its elevation is mostly from 200 to 300 feet, and the seaward slope is 10 to 20 feet to the mile. This plain, with its fertile soil and delightful climate, is covered with settlements, cultivated fields, vineyards, and vast orchards of oranges, lemons, walnuts, olives, and other fruits. Shade trees and flowers are extensively cultivated. To this wealth of resources on the surface is added a large production of petroleum, which has been developed most profitably at many places.

The Los Angeles River is crossed in the eastern outskirts of the city of Los Angeles, and the train proceeds slowly through streets for about 3 miles to the depot. Most of the city is built on low river terraces and on the inner edge of the coastal plain, but the newer sections extend onto the hills of folded and faulted Tertiary sandstone and shale that rise to the north. The Los Angeles River, like many other streams of the Southwest, is ordinarily of small volume, but during heavy rains it is considerably swollen, and at times it becomes a deep torrent capable of doing considerable damage.

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Los Angeles.
Elevation 253 feet.
Population 1,238,048.
New Orleans 2,002 miles.

Los Angeles is the largest city of the Southwest, in area, population, and business. Founded in 1781 by a garrison of Mexican soldiers from the mission of San Gabriel, in 1831 it had a population of 770, and as late as 1880 it was an easy-going semi-Mexican town of 12,000 inhabitants centered about the old plaza with the mission church of Nuestra Señora la Reina de los Ángeles (Our Lady the Queen of the Angels), from which the city takes its name.

At La Mesa battlefield, now the stockyards on Downey Road, there was on January 9, 1847, a battle between the Americans and Californians which resulted in the capture of Los Angeles by the American forces.

Among many historical episodes in Los Angeles one of the most important was the truce signed on January 13, 1847, by Gen. Andrés Pico, which when ratified gave to the United States all of the territory west of the Rocky Mountains south of Oregon. This event occurred at Campo de Cahuenga, now 3919 Lankershire Boulevard. At the southeast corner of Los Angeles and Aliso Streets is the building in which General Frémont had his headquarters while he was military governor of California, and here the city of Los Angeles was organized in 1850.

With the coming of the Atchison, Topeka & Santa Fe Railway in November, 1885, homeseekers began to arrive, and a great increase in property values and growth of the city followed. The census showed that Los Angeles made a greater percentage of increase in population from 1880 to 1900 than any other city in the United States, and there has been a remarkably rapid increase since that time, amounting to nearly 115 per cent in the decade 1920–1930. The city is the largest in area in the United States, comprising within its limits 442.5 square miles. In addition to the salubrity of its climate, which attracts citizens from all over the United States, two important factors in its growth have been the generation of electricity from mountain streams as far as 226 miles away and the availability of cheap petroleum fuel. The economical power thus available has developed a very large manufacturing center.

Los Angeles has had to provide a vast amount of water for its rapidly growing population. At first local supplies were used, but later an aqueduct was constructed to bring water from Owens Valley, 226 miles distant, at a cost of about $25,000,000. Its capacity is 250,000,000 gallons a day. As still more water will be required in the future, it is planned to bring in a supplemental supply from the Colorado River at Parker after the Boulder Dam is completed. (See p. 241.)

Los Angeles County, with an area of only 4,115 square miles, claims to be the richest county in the United States in value of farm property and agricultural products. According to the United States census reports it produces more than one quarter of the oranges, lemons, and walnuts (nearly 20,000,000 pounds), and more than 10 per cent of the grapefruit (157,500 boxes) grown in the State. The milk production in 1929 was more than 47,000,000 gallons. The mean annual temperature of Los Angeles is 62°.

The harbor at San Pedro, called the Port of Los Angeles, on the ocean 25 miles south of the center of the city, has a large coast and trans-Pacific trade. Its exports in 1929 were valued at $166,328,683 and the imports at $63,685,483 (U. S. Department of Commerce). Los Angeles has four large educational institutions—the University of Southern California, the University of California at Los Angeles, Loyola College, and Occidental College. The Public Library is a handsome edifice and, besides the usual material, contains a large collection of books of reference.

The Museum of History, Science, and Art in Exposition Park has fine collections in many fields and controls the remarkable fossil bone deposits in the asphalt springs of Rancho La Brea (pl. 48, *B*), about 8 miles directly west of the center of the city. These springs of tarry material due to seepages of petroleum which have oozed up from an underlying stratum have been for centuries most effective animal traps. The asphalt has accumulated to depths of 15 to 30 feet and has preserved the bones of thousands of extinct as well as modern animals which were caught in its sticky pools.[95] The skeletons of elephants, camels, ground sloths, lions, saber-toothed tigers, wolves, bears, and myriads of smaller animals, including 50 species of birds, have been dug out and set up in the museum. (See fig. 69.) Carnivorous quadrupeds predominated, a fact which indicates that animals venturing out on the seemingly solid surface were caught in the viscid asphalt and served as a bait to lure their bloodthirsty neighbors, who in their turn were also trapped and unable to extricate themselves. These animals lived mostly during the Pleistocene epoch, when the northern part of this continent was buried under great fields of ice, but some of them represent later times. In one pit was found a skull of a human being, who may have lived 10,000 years or more ago, contemporaneously with some of the later animals now extinct, but is regarded as belonging to a later date than most of the animals.

[95] According to Stock, the most abundant mammals are the saber-toothed tiger (*Smilodon californicus*) and the dire wolf (*Arenocyon dirus*), which are represented by thousands of bones. There were also the great lionlike cat (*Felis atrox*), the coyote (*Canis ochropus orcutti*), and the short-faced bear (*Tremarctotherium californicum*). Among the herbivores were the mammoth (*Archidiskodon imperator*), mastodon (*Mammut americanum*), horse (*Equus occidentalis*), bison (*Bison antiquus*), camel (*Camelops hesternus*), antelope (*Capromeryx minor*), and several kinds of ground sloths (*Mylodon harlanii*, *Nothrotherium shastense*, and *Megalonyx jeffersonii*). Among the great numbers of condors, vultures, eagles, and hawks is the largest bird of flight, a condorlike vulture (*Teratornis merriami*).

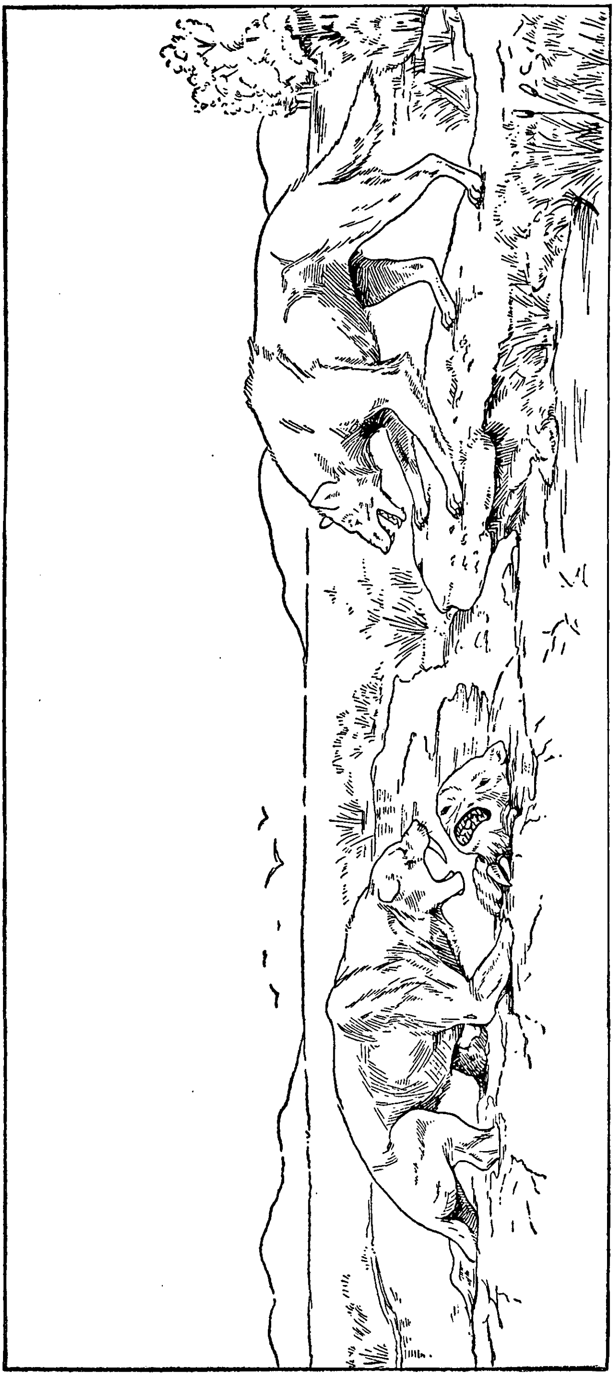


FIGURE 69.—Restoration of saber-toothed tiger, sloth, and dire wolf at La Brea, Calif. By E. Christman

The Los Angeles region is underlain by a thick succession of Tertiary and Cretaceous strata, some of them deeply buried and others presenting prominent outcrops, especially in the hills and mountains. They are flexed, tilted, and faulted and vary considerably in character from place to place. The eastern part of the Santa Monica Mountains, projecting into the northern part of the city, contains an extensive uptilted succession of the rocks that underlie the region. At the base are old slates and schists (Triassic?) cut by granites and granodiorites, similar to those in some other ranges of southern California. They are overlain by a thick body of conglomerate, sandstone, and shale of Upper Cretaceous and Tertiary age.

Formations in Santa Monica Mountains

[H. W. Hoots]

Formation	Thickness (feet)	Age
Shale, with beds of sandstone and ash (Modelo formation)	4,500	Upper Miocene.
Unconformity (folding, faulting, and basalt intrusions).		
Sandstone, conglomerate, shale, basalt flows, and other volcanic rocks (Topanga formation). Basal 1,000 feet of conglomerate east of Cahuenga Avenue may be Vaqueros.	4,500–7,500	Middle Miocene.
Light-gray and red conglomerate (Vaqueros? and Sespe? formations)	3,500–4,000	Lower Miocene and Oligocene(?).
Unconformity.		
Shale and sandstone; some fossiliferous sandstone (Martinez formation).	250+	Lower Eocene.
Conglomerate, sandstone, and dark shale, fossiliferous (Chico formation).	8,000±	Upper Cretaceous.

In the hilly region southeast of the Santa Monica Mountains, and mainly in the east-central part of Los Angeles, younger formations are also present, notably sandstones, conglomerates, and clays of Pliocene age, which overlie the Miocene beds. These are in turn overlain unconformably by the terrace and alluvial deposits of the Los Angeles Plain, above referred to.

The east end of the Santa Monica Mountains is an open anticline, the axis of which is in a broad central area of Santa Monica slate (Triassic?) and plunges westward from the main granite mass just north of Hollywood. Although the general structure is anticlinal, the original folding is much complicated by faults, flexures, and igneous intrusions. Post-Modelo flexing resulted in widespread anticlinal uplift. In the Martinez formation, and possibly also in the Chico formation, are prominent reefs of limestone 50 to 60 feet thick, the largest one being 500 feet long. (Hoots.) The Santa Monica Mountains extend to the Pacific Ocean at Santa Monica. (See pl. 48, *A*.)

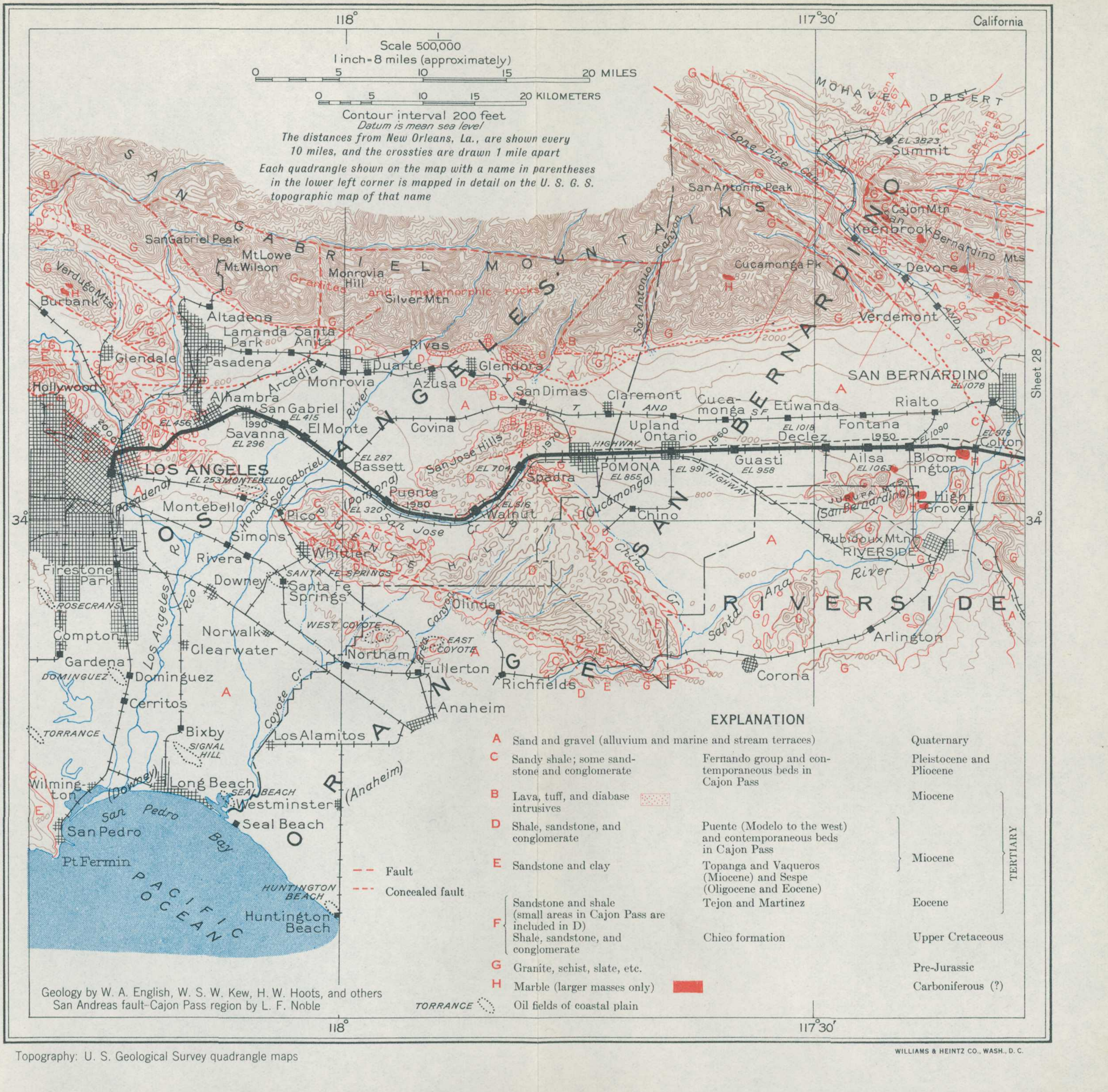
In the central part of Los Angeles are many exposures of Miocene beds, including shale filled with diatom remains. On Hill and First

Streets above the tunnel are exposures of these shales overlain by dark, massive sandy shale of Pliocene age. Good sections of the Topanga formation (middle Miocene) appear on Glendale Boulevard between the Los Angeles River and Los Angeles, where the formation is 2,000 feet or more thick and the beds dip to the south. A conspicuous Miocene sandstone is exposed in Elysian Park. The general structure about Los Angeles is that of a syncline or basin bordered in part on the north and east by faults.

At Elysian Park, along the west side of the Los Angeles River, the railroad cuts expose sandstones of middle Miocene age overlain by upper Miocene shales. These beds are on the south limb of an extensive anticline whose axis lies in the bed of the river farther north. On Fifth Street, opposite the Public Library, upper Pliocene fossiliferous beds are well exposed. The strata east of the river consist mainly of highly folded middle and upper Miocene beds. (Kew.)

The hills in northern Los Angeles and western Alhambra consist of a thick succession of Miocene, Pliocene, and Pleistocene strata comprising conglomerate, sandstone, siltstone, and shale. In the upper Miocene are many beds of siliceous and diatomaceous shale. The total thickness of these strata is apparently 11,000 feet. They lie on the older granites and metamorphic rocks. The Miocene rocks are exposed in many street cuts east of Lincoln Park adjacent to Valley Boulevard. Upper Miocene (Puente) shale and interbedded sandstones are exposed near City Terrace. (R. D. Reed.)

In the central part of Los Angeles is a belt of petroleum-producing territory 5½ miles long, covering an area of 2 square miles. Here hundreds of derricks have been erected in close proximity to dwellings. This field was discovered in 1892 by a 155-foot shaft sunk near a small deposit of brea or asphalt on Colton Street. The first good strike of petroleum was made in a well on Second Street, and by the end of 1894 there were 300 producing wells from 500 to 1,200 feet deep. The wells have been small producers, averaging 2½ barrels a day each by pumping, and now much of the area is drained of its oil. The Salt Lake field is also within the city limits, about 4½ miles west of the business center. It was started in 1901 and has been a notable producer, having 700 wells in 1914. The wells are mostly from 1,200 to 3,000 feet deep, and in most of the area there has been considerable gas, which caused the wells to gush in the early part of their life. The average production per well was 23 barrels a day, and the total production from 1894 to the end of 1931 was over 60,000,000 barrels. (Hoots.) The oil has been mainly useful for fuel. The petroleum in the Los Angeles district is derived largely from the upper 500 feet of the Miocene and the basal beds of the Pliocene. The oil pools are thought to be related to slight arching along the younger dis-



Topography: U. S. Geological Survey quadrangle maps

WILLIAMS & HEINTZ CO., WASH., D. C.

placements. (Eaton.) Faulting has had much to do with the accumulation of the oil. The most productive fields are on anticlines having the form of elongated domes, but some of the folds are of the plunging variety, with their upper ends sealed by asphalt or by an overlapping impervious bed. (Kew.)

YUMA, ARIZ., TO SAN DIEGO, CALIF.

Sleeping cars from several trains continue westward from Yuma to San Diego over the San Diego & Arizona Railway, which is allied with the Southern Pacific lines. The distance is 218 miles, across Imperial Valley and the high sierra of southern California, with two long detours into Baja California. This railroad was completed in 1919 at a cost of $19,000,000. It has 22 tunnels, one of them about half a mile long.

El Centro.

Elevation –49 feet.
Population 8,434.
New Orleans 1,830 miles.

The main line is left at Araz Junction, 6½ miles west of Yuma, on Southern Pacific tracks extending to El Centro (40 miles). The railroad passes around the southeast end of the great belt of sand hills and looping into Mexico reaches Mexicali, Mexico, and the adjoining city of Calexico, Calif. El Centro is in the highly productive irrigated district of Imperial Valley. (See p. 248.) The New River, an old channel from the Colorado River, touched by the railroad at Calexico and crossed a short distance west of Seeley, occupies a trench in the desert plain much deepened and widened by the great flood of water that ran through it into Imperial Valley from the Colorado River in 1905. This stream ate deeply into the adjoining banks and damaged more than 7,000 acres of the adjacent region. The Alamo River, 10 miles east of El Centro, was another inlet for flood waters.

From Seeley westward there are fine views of Signal Mountain, a knob of old granite and schist not far away in Mexico, and of the Sierra de las Cocopas, consisting of volcanic rocks, which extend far to the south. Farther west is dimly outlined the high Sierra Pedro Martir (mar-teer′), in Baja California, which attains an elevation of more than 10,000 feet. It consists of light-colored granite. The northern extension of this range, known as the Laguna Mountains, is crossed by the railroad near Jacumba, about 50 miles farther on, where, however, the elevation is much less than in Mexico. The continuity of its steep eastern front, believed to be a fault scarp, is a striking feature for many miles. The West Line Canal, just east of Dixieland, separates the productive irrigated land, with its fine fields of cotton, alfalfa, barley, and maize, from the original desert, with its sparse vegetation of arid-land plants.

Just west of Dixieland sea level is reached on an up slope of the desert which continues westward to the foot of the mountains. Three miles west of Dixieland the beach of old Lake Cahuilla is crossed at about 40 feet above sea level. This lake occupied the Salton Basin sufficiently long to develop well-marked strand features. (See p. 253.) At Plaster City is a mill making plaster of paris from gypsum mined from large deposits in Fish Creek Mountain, 26 miles northwest, and brought by a branch railroad. The deposit is interbedded in strata of Tertiary age, and near by is a considerable body of the mineral celestite (strontium sulphate), also included in the sedimentary succession.

Halfway to Coyote Wells a low ridge is crossed showing tilted clay and sand of Tertiary age, truncated and capped by a thin mantle of sand and gravel. This ridge crosses the valley and rises into Coyote Mountain, which is conspicuous to the north. This mountain and Fish Creek Mountain, just beyond, consist mainly of a core of granite and marble and other metamorphic rocks, closely folded and encircled by Tertiary and later strata. The marble, which may be of Paleozoic age, is penetrated and metamorphosed by the granite. It is mostly of blue-gray color and has been quarried to a small extent at the east end of Coyote Mountain. Some portions contain con-

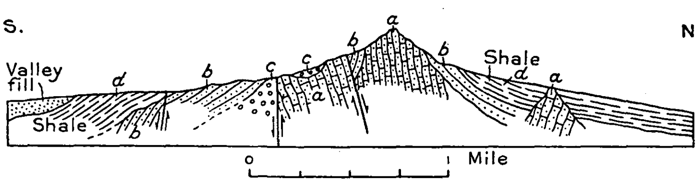
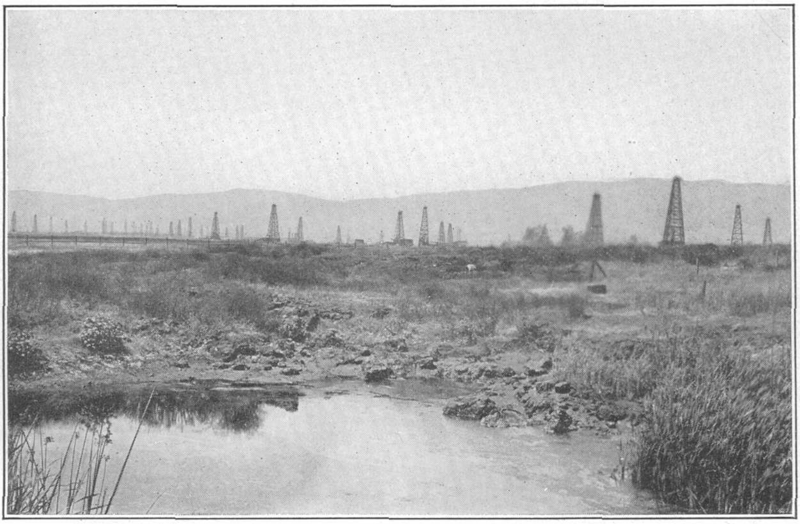


FIGURE 70.—Section across Coyote Mountain, Calif., near Alverson and Garnett Canyons. After Mendenhall. *a*, Limestone (Paleozoic) metamorphosed to marble by intrusive granite; *b*, sandstone and conglomerate; *c*, tuff (Miocene); *d*, shale (Miocene)

siderable graphite in the form of carbon known as plumbago or black lead. A section through Coyote Mountain is shown in Figure 70.

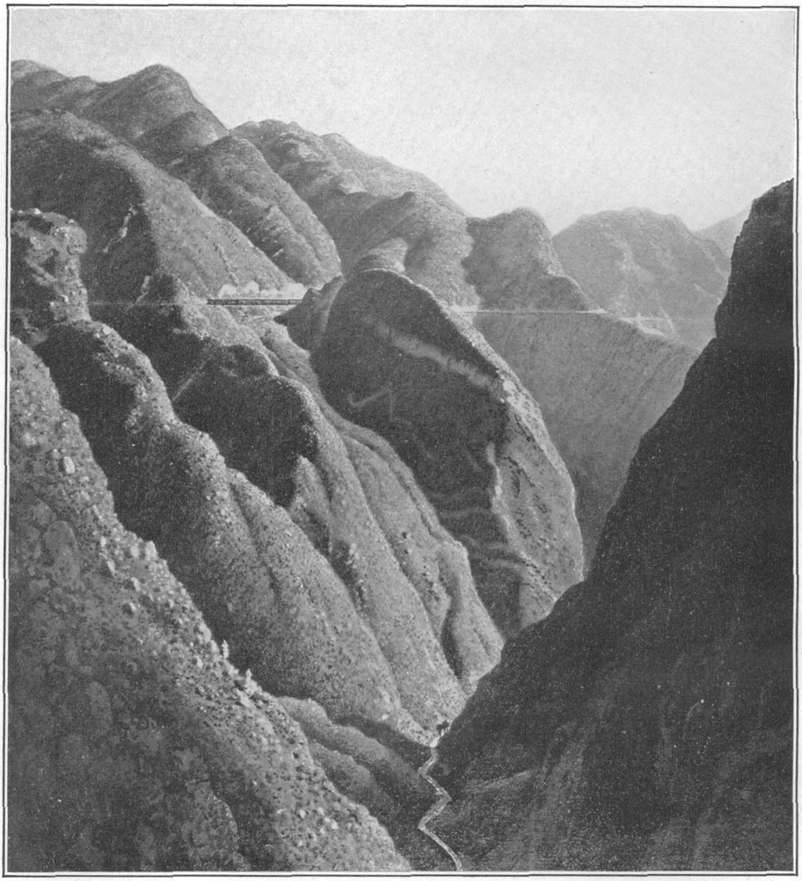
Lying on the metamorphic and intrusive rocks is a series of volcanic tuffs, agglomerates, and dark lavas which carry interbedded sandstones in Fish Creek Mountain. Upon these lie marine beds with corals and oyster reefs, containing many fossils. In Alverson Canyon on the south side of Coyote Mountain, red vesicular lava is overlain by green and lavender sandstones and conglomerate containing much volcanic matter, in all from 100 to 200 feet thick. Next above are tawny sandstones and a thick succession of soft greenish-yellow shale or clay which forms conspicuous badlands in the slopes between Carrizo Mountain and Fish Creek Mountain. High-level terrace deposits lie across the planed-off edges of the shale. The Tertiary beds and their fossils have been described by Mendenhall, Kew, T. W. Vaughan, and Woodring.

A. SHORE OF THE PACIFIC OCEAN AT SANTA MONICA, CALIF.



B. ASPHALT PITS AT LA BREA, IN THE WESTERN PART OF LOS ANGELES, CALIF.

Oil field in middle ground; Santa Monica Mountains in distance.



CARRIZO GORGE, ON ROUTE FROM YUMA, ARIZ., TO SAN DIEGO, CALIF.
From painting by W. H. Bull.

Tertiary beds also constitute the Yuha Buttes, 8 miles west of Dixieland. Among many fossils occurring in the sandstones on these mountains are numerous corals, many of them finely preserved. According to Vaughan, this coral fauna, which is considered to be of early Pliocene age, contains forms not found in the Pacific Ocean. Its Atlantic Ocean affinities indicate that in late Tertiary time there was an oceanic connection that permitted the Atlantic fauna to extend to the head of the Gulf of California; this connection, however, may have been as far south as the Isthmus of Tehuantepec. Fossils, especially scallop shells, occur in large numbers about Carrizo Mountain and near Yuha Wells, 6 miles southwest of Dixieland.

West of Coyote Wells and extending far south and north is the steep east front of the Laguna Mountains, which form the extension of the Sierra Pedro Martir of Baja California. The range presents cliffs and rugged slopes of white granite, which are climbed by the picturesque main highway to San Diego, an ascent of more than 2,500 feet, passing through Mountain Springs at the foot of the mountains and Jacumba Springs near the top. At the foot of this slope in places are hills of old gravel and boulder deposits rising considerably above the main valley slope and capped by lavas. The railroad ascends the valley and near Dos Cabezas siding reaches the base of the Laguna Mountains, in which are exposed marble and schist apparently underlying the great mass of granite which rises so abruptly to the westward. A mile beyond Dos Cabezas foothills of granite are entered and the low divide into Carrizo Valley is crossed. Thence the railroad swings southward and ascends this valley and the deep Carrizo Gorge, at its head. The gorge is about 11 miles long, and there are many deep cuts, tunnels, and long shelves cut on the precipitous slopes, in places 900 feet above the creek. The scenery is remarkably impressive. The rock is mostly a massive light-colored granite, sculptured into many picturesque forms in the steep canyon walls. (See pl. 49.) The effects of jointing and erosion are well shown. It is believed that this valley is developed along a fault. Carrizo is the local name for the grass growing in the depths of the gorge and used by the Indians in basket making. Palms also grow in several places near the stream bed.

At the head of the deep canyon the railroad comes out into a park which extends about 3 miles to Jacumba Springs. This park is due to a dropped block of lava on tuffs (Tertiary) which caps the granite in an area of several square miles in this region. The sketch section in Figure 71 shows some of the features.

At Jacumba Springs (elevation 2,830 feet), where the granite appears again, there are warm springs with faint sulphureted hydrogen emanation and notable mineral contents. Here a resort has been developed. The water was used by Indians and early aborigines, who have left many traces of their presence. North of Jacumba there is a belt of schists, slates, and other metamorphic rocks which are regarded as Paleozoic. West of Jacumba there is a long ascent up the granite slope to the summit at Hipass (elevation 3,660 feet). In this region the granite is weathered into many grotesque forms, mostly rounded, with numerous balanced rocks and rugged pinnacles. Pronounced jointing has had much to do with the development of these features. The granite of the entire range is mostly light colored, of uniform grain, and very massive, so that much of it would make a fine building stone. It is cut by dikes of darker rocks, and there are zones in which the jointing is closely spaced and the rock considerably shattered.

The mountain vegetation is very different from that of the desert, with much manzanita and live oak. The manzanita (*Arctostaphylos patula*) is a shrub having a smooth bark of rich chocolate-brown color, small pale-green roundish leaves, and berries that resemble diminutive apples. It is this resemblance that gives the shrub its common name, which in Spanish signifies little apple. Bears are very fond of these berries. The manzanita covers many of the hills in California with a

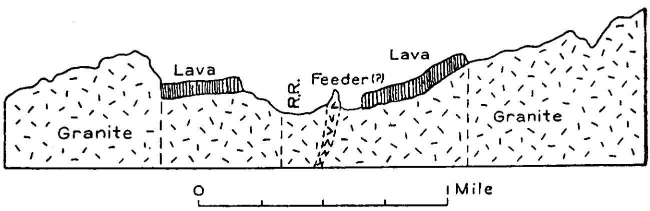


FIGURE 71.—Section about 2 miles north of Jacumba Springs, Calif.

stiff, almost impenetrable growth. Its wood is hard, and the blaze from an old gnarled root cheers many a western fireplace. The live oak grows generally in the valleys, for the mountains are mostly covered by bushes with many bare rocky spots. The summit is broad and rolling, with parks at intervals. The country near the pass is not high enough for pine, which occurs on the adjoining highlands. On the west side of the pass the railroad makes a long tortuous descent through the Campo Indian Reservation into the valley of Campo Creek, which is followed to a point considerably below Campo.

Campo is a small settlement in a parklike valley surrounded by granite hills on which are many great residual boulders of granite. This granite is the source of fine gems at various places in San Diego County, notably tourmalines of red, green, and pink colors. A rare form of spodumene known as kunzite occurs in crystals of beautiful purple and violet tints. Garnets and beryls are also obtained, and some of the beryls are white or pale rose and almost as brilliant as diamonds.

Between Campo, Calif., and Tecate, Mexico, the international boundary line is crossed in tunnel 4, the deflection into Mexico being required to obtain a suitable grade for the railroad on the west side of the mountain. For the next 43 miles the track follows the northern margin of Baja California. A long descent is made in a great S-shaped course to Redondo, a small village in a wide granite valley with high ridges on all sides. This valley is followed to the west, finally down a deep gorge in porphyry (beyond Matanuco) which leads out into the coastal plain of the west coast of California. This plain is a smooth high terrace of gravel and sand (Pleistocene or late Tertiary), deeply trenched by the valley of Tia Juana Creek (tee′a wah′na, Spanish for Aunt Jane), which the railroad follows to the city of Tia Juana. Two miles east of the city it passes the picturesque resort of Agua Caliente, with casino, hotel, race course, and other features, where annual handicap horse races and golf tournaments are held.

From Tia Juana the railroad turns north into the United States and, crossing a low coastal terrace plain, reaches San Diego in a distance of 16 miles.

San Diego.
Elevation 10 to 200+ feet.
Population 147,995.
New Orleans 1,978 miles.

The beautiful city of San Diego has developed about a fine harbor in the southwest corner of California. The mild winter climate and temperate summers have had much to do with attracting a large population. The harbor was discovered by the Portuguese navigator, Juan Rodríguez Cabrillo, in September, 1542, and was named in 1602 by Don Sebastián Vizcaino, a Spanish explorer. The first mission in California was the Mission San Diego de Alcalá, founded at a small Indian ranchería (site of present Old Town) by Padre Junípero Serra in July, 1769; it was moved to the present location in 1774. Destroyed without warning by the Indians in 1775, it was reestablished in 1776 and flourished until secularized in 1834. Mexican administration of the settlement was organized in 1822. The city is built on marine plains and terraces which slope seaward from the Cuyamaca Mountains (coo-ya-mah′ca) on the east and the Ysidro Mountains (ee-see′dro) to the south. The harbor is used by many large ocean vessels, and along its margin are the United States Naval Station, Fort Rosecrans, and the Army and Navy aviation headquarters. Many fine beaches, notably Coronado, with its tent city and hotel, and Mission Beach, attract large numbers of visitors. Balboa Park, 1,400 acres in extent and of great beauty, contains museums of natural history and art, housed in some of the handsome buildings built for the exposition of 1915. At Old Town, on the north edge of the city, are the old mission, old Fort Stockton, the monument where in 1846 General Frémont first planted the United States flag, and the marriage place of Helen Hunt Jackson's "Ramona."

The Point Loma peninsula, which separates the ocean from the bay, is a residential section and the headquarters of the Theosophical Society. This peninsula is underlain by soft shales and sandstones, carrying fossils of Chico (Upper Cretaceous) age capped by cliff-making conglomerates of late Tertiary age and to the north passing under sandstones carrying Eocene fossils. The famous sea cliffs of La Jolla (hoe'ya) are 14 miles north, and near them is the Scripps Institution of Oceanography of the University of California. In these cliffs and adjacent areas Cretaceous and Eocene strata are exposed.

The temperature of the San Diego region is very rarely below 32° or above 90°. Myriads of flowers and abundant shade trees are notable features. Oranges, lemons, and other fruits, besides vegetables in great variety, are grown in the adjoining region. One large industry at San Diego is milling lumber brought down the coast from Oregon in huge rafts.

HISTORY OF THE RAILROAD

The railroad from New Orleans to Los Angeles is part of an extensive system with many individual members, of which the Southern Pacific Co. owns all or very nearly all of the capital stock. The line from Algiers to Lafayette now known as Morgan's Louisiana & Texas Railroad & Steamship Co. was incorporated in 1852 as the New Orleans, Opelousas & Great Western Railroad Co. It reached Morgan City (Brashear) in 1857 and Lafayette in 1880. It was operated by the United States during the Civil War and owned by Charles Morgan from 1870 to 1878. The Louisiana & Western Railroad Co. was built from Lafayette to the Sabine River in 1881, and the Texas & New Orleans Railroad Co. was constructed from Orange to Sabine River (Echo) in 1878–81. The latter was operated as part of the Louisiana Western Railroad until 1900. The Sabine & Galveston Bay Railroad & Lumber Co., later the Texas & New Orleans Railroad Co., built a line from Houston to Liberty in 1856–60 and from Orange to Liberty in 1859–60. It was dismantled by the Confederates in 1865 and restored in 1870. The line from Houston to El Paso, known as the Galveston, Harrisburg & San Antonio Railway, was also built in sections. The portion from Harrisburg (now a part of Houston) to Alleyton was built by the Buffalo Bayou, Brazos & Colorado Railway Co. in 1853–60 and extended to Columbus by the bridge across the Colorado River before 1870, including 2½ miles of road to the river built in 1861–65. The line from Columbus to San Antonio was constructed mostly in 1873–77, and the line thence to El Paso was built in 1881–82 by a contractor recompensed by bonds and capital stock. From Sierra Blanca to El Paso the tracks are used jointly by the Texas & Pacific Railway on a rental basis.

The lines west of El Paso were built in separate portions by local Southern Pacific organizations, since 1902 combined in the one general company. The tracks were laid from Yuma to El Paso in 1879–81, and the line from Los Angeles to Yuma was built in 1873–77.

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